Indiana Water Resources Research Center
Annual Technical Report
FY 2015

Introduction

Overview: This report covers the activities of the Indiana Water Resources Research Center (IWRRC) for the period March 1, 2015 to February 28, 2016 and was written by Ronald F. Turco, former Director of the center. The new Director of the Center is Dr. Linda Prokopy, Professor in the Department of Forestry and Natural Resources, Purdue University, she took over on March 1, 2016. This report is provided to meet requirements and obligations under the 104 (B) of the USGS water centers program. The objectives of the fiscal year 2015 program of the IWRRC have been: (1) to continue to engage the water community in the State of Indiana as related to water research and education; (2) to chair the dedicated water community at Purdue University–the Purdue Water Community (http://www.purdue.edu/dp/water/about.php) and build a water faculty at Purdue (http://catalog.e-digitaleditions.com/i/351089-protecting-indianas-water-future) ; (3) foster a research programs that encompass water issues related to: contaminants and plant nutrients that may find end up in the waters of the state; (4) continue to support an outreach program related to water and water quality (in particular rural water protection/safety), (5) to strengthen interactions with State regulatory agencies, the Agriculture Industry, water industry and Federal Agencies, meetings with USGS, and Indiana Department of Natural Resources and (6) organize and run the Indiana water forum. In the last year we have supported externally reviewed 104(B) projects, maintained a functional website (www.iwrrc.org) been involved in the development, submission and management of number of grant proposals including 104g submissions. In terms of web resources we have worked with the digital library to ensure all of our back reports are available via the Purdue University Library at “IWRRC Technical Reports”(http://docs.lib.purdue.edu/watertech/).

The IWRRC and Wabash River Enhancement Corporation (WRRC) have maintained a strong relationship over the past year. We are now in the final year of our project entitled "Region of the Great Bend of the Wabash River Implementation project” where IWRRC is active with WREC in helping to evaluate projects for potential cost-share under the implementation effort. One of our small research projects was a result of questions raised as part of the relationships. The IWRRC-WREC collaboration led to project entitled “Deer Creek-Sugar Creek Watershed Management Plan and Implementation Program” which has been finalized. We also completed a project entitled the “Sugar Creek Water Sampling Project” working with the Clinton County Soil and water district to better understand regional impacts on water quality. The IWRRC has been active with the Purdue University water community (PWC) and have facilitated a number of campus wide meetings to engage this group. We have been primarily interested in developing grant applications as part of the new NSF INFEWs program. International, we have continued to work with Purdue’s office of global engineering on a number of water projects with efforts in China and Colombia. We have worked with the Purdue University Ecopartnership (http://www.purdue.edu/discoverypark/ecopartnership/) and were active in hosting a major meeting in the fall of 2015. Our goal has been the development of effective partnerships leading to real improvements in water quality. For this reporting period, we continue our strategic outreach alliance with the Purdue Pesticide Program office for the development of document and educational materials on methods to prevent water contamination. By leveraging our funds with the Purdue Pesticide Program office’s core efforts we are using the opportunity to include the IWRRC in many of their programs. Our efforts have established a constant and vital outreach effort that is associated with prevention rather than remediation of environmental problems. We are currently looking for other extension efforts that could be supported in a similar manner.

Project 01: Program Administration and State Coordination

The administrative portion of the project has been used to support the management of the IWRRC's research projects and to facilitate the development of other research projects. We have also stepped up our efforts to coordinate campus level interactions and interactions with state and federal agencies. All of these efforts have the ultimate goal of improving the quality of water resources in the State of Indiana. We have used a limited amount of money on the administrative portion but it has allowed the IWRRC director some means to invest time in the efforts to integrate with state and federal agencies. Most of IWRRC funds are used for projects and the director's time is contributed to IWRRC efforts. The IWRRC director has worked with state and federal environmental agencies, the governments of Indiana's cities and counties and key citizen groups on water education and water resources planning activities. In this way, the results from the research projects can be transferred to interested individuals in the state. The IWRRC director has participate in important national and international meetings related to water and environmental protection.

Projects Areas

1. Work with community projects has continued including working with the Wabash River Enhancement Corporation (WREC) on a Volunteer Water Quality Monitoring project to allow opportunities for volunteer monitors to assess water quality conditions throughout the watershed. WREC its partners conducted a fall and spring Wabash River Sampling Blitz in 2015. Connecting volunteers to the Wabash River: During each spring and fall event, approximately 175 volunteers mobilize to collect water samples from 258 stream sites within the Region of the Great Bend of the Wabash River and Wildcat Creek watersheds. The Wabash Sampling Blitz is dedicated to helping watershed residents learn more about the quality of the Wabash River. This portion of the Blitz provides information to the community through various media outlets, public information discussions, the WREC Wire (e-newsletter), the Wabash Sampling Blitz website and via partner newsletters and programs. During the previous 10 events (going back 5 years), volunteer groups sampled three to four stream sites collecting field measurements for temperature and transparency, using test strips to analyze pH and nitrate at a minimum, and filling sample bottles for laboratory analysis of E. coli, nitrate+nitrite, orthophosphorus, and total organic carbon. Sample results were mapped by subwatershed drainage and posted to www.wabashriver.net as soon as possible following the event. In total 600 unique volunteers participated in the sampling blitzes. More importantly results from the efforts have been recently published "The Wabash Sampling Blitz: A Study on the Effectiveness of Citizen Science" (http://theoryandpractice.citizenscienceassociation.org/article/10.5334/cstp.1/) in the new journal, "Citizen Science: Theory and Practice" which is an open-access, peer-reviewed journal published by Ubiquity Press on behalf of the Citizen Science Association. The journal focuses on advancing the field of citizen science by providing a venue for citizen science researchers and practitioners

2. Organized and ran a second major water conference "Indiana Water Forum: Managing Indiana's water, a discussion" November 12. 2015, The Beck Agricultural Center, Purdue University 4540 U.S. 52 West, West Lafayette, IN 47906. We had well over 130 in attendance from all aspects of the Indiana water community. Speaker and Topics: a. Welcome – Ronald F. Turco, Director of the Global Sustainability Institute, IWRRC and Assistant Dean for Agricultural and Environmental research, College of Agriculture b. Opening remarks – Ed Charbonneau, State Senator–Indiana District 5 c. Keynote: Water Sustainability - Can We Get There? Dr. Deborah L. Swackhamer, Professor Emeritus of Science, Technology, and Public Policy in the Humphrey School of Public Affairs, and Professor of Environmental Health Sciences in the School of Public Health. University of Minnesota d. Developing and managing Indiana's water systems –Thomas M. Bruns, President Aqua Indiana, Inc. e. Water as an economic driver for Indiana – Vince Griffin, Vice President, Energy and Environmental Policy Indiana Chamber f. What can "the water people" learned from the electricity forecasters – Doug Gotham. Director of State Utility Forecasting Group, Purdue University g. Critical Water Issues We Need to Address. Otto Doering, Professor Agricultural Economics Purdue University h. Water and the environment. Tom Davenport, USEPA Region 5 i. Water and agriculture. Justin Schneider, Sr. Policy Advisor and Counsel Public Policy Team Indiana Farm Bureau j. Indiana irrigation now and in the future – Lyndon Kelly Irrigation Educator Purdue University and Michigan State University k. Planning for a water contamination emergency, research and education needs – Andrew Whelton, Purdue University

3. Attendees over 130 attended for the event from: i. University Faculty from (Purdue, IU, Ball State, IGS, IUPUI) ii. Industry Members from (Duke, KCI tech, Burke Eng., Citizens) iii. Environmental groups (TNC, WREC, HEC) iv. Regulatory/government (IDEM, IDNR, ISDA, NRCS, state senatros and representatives and

the Governor’s office)

4. In conjunction with the Tippecanoe County soil and water conservation district office, we working with cover crops to reduce N leaching and runoff as well as to improve soil health. This links to the use of infield anaerobic bioreactors as a means of reducing soluble N that can be discharged to surface water.

Grant Applications Submitted thorough/with IWRRC:

a. (Submitted) IDEM-319 $750,000 St. Marys Watershed Initiative b. (Submitted) INFEWSt2 $2,920,034 Sensors and data-driven inductive transfer learning to reduce watershed nitrogen pollution c. (Submitted) USEPA $2,000,000 Right sizing tomorrow’s water systems for efficiency, sustainability and public health. d. (Submitted and pending) Great Lakes Research Initiative. 500,000 Soil quality assessment and monitoring at GLRI edge-of-field sites. e. (Funded and ongoing) $70,000 Indiana Water Finance An Assessment of Indiana’s current and future irrigation water needs. f. (Funded and ongoing) IDEM-319 $94,835 Clinton Cty Soil Water Dist Sugar Creek Water Sampling Project g. (Funded and ongoing) USDA-CIG $165,000 Using cover crops to improve soil health and moisture retention. h. (Funded and ongoing) IDEM-319 $240,000 Region of the Great Bend of the Wabash River Implementation Project with L. Prokopy, S. Peel and R. Goforth.

i. (Closed) USDA-CAP: $2,875,642 Sustainable Production and Distribution of Bioenergy for the Central USA with J. Volenec, S. Brouder, others

j. (Closed) IDEM-319 $132,000 Deer Creek-Sugar Creek Watershed Management Plan and Implementation Program. Project with S. Peel and R. Goforth.

k. (Closed) SUNGRANTS: Optimization of biomass productivity and environmental sustainability for cellulosic feedstocks: Land capability and life cycle analysis. $875,000 S.M. Brouder, PI, R.F. Turco, J.J. Volenec, D.R. Smith and G. Ejeta CoPIs

Associate Director: Dr. Linda Prokopy, Professor Forestry and Natural Resources

External Board of Advisors Membership: Dr. Jack Wittman, Ph.D., Bloomington IN Dr. Bill Guertal Director, USGS Indiana Water Science Center, Indianapolis IN Mr. Jeff Martin, USGS Indiana Water Science Center, Indianapolis IN

Faculty Advisory Committee: Dr. Linda Lee, Professor and Director of ESE Dr. Indrajeet Chaubey, Agriculture and Biological Engineering Dr. Larry Nies, Civil and Environmental Engineering

Research Program Introduction

None.

Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices

Basic Information

Title:	Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices
Project Number:	2014IN377G
USGS Grant Number:	
Start Date:	9/1/2014
End Date:	8/31/2017
Funding Source:	104G
Congressional District:	IN-4
Research Category:	Water Quality
Focus Category:	Water Quality, Management and Planning, Non Point Pollution
Descriptors:	None
Principal Investigators:	Laura C. Bowling, Linda Stalker Prokopy

Publication

1. Gao, Y., N. Babin, A.J. Turner, C.R. Hoffa, S. Peel, and L.S. Prokopy, 2016. Understanding urban-suburban adoption and maintenance of rain barrels, Landscape and Urban Planning http://www.sciencedirect.com/science/article/pii/S0169204616300330

General Report Format

Report Format

Project Id: 2014IN377G

Title: Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices

Project Type: Research

Period: March 1, 2015 – February 28, 2016

Congressional District: Indiana 4

Focus Categories: Water Quality, Management and Planning, Non Point Pollution

Keywords: urban stormwater BMPs, social indicators, water quality

Principal Investigators: Bowling, L.C. and L.S. Prokopy

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Abstract/Summary: Stormwater management, including the infrastructure for water conveyance, drainage and treatment, is an increasing water problem for communities of all sizes. This project is addressing the need to improve and enhance the nation's water supply through evaluation of what limits adoption of urban stormwater conservation practices. Stormwater conservation practices, such as rain gardens, rain barrels and permeable pavement offer the potential of decreasing stormwater volumes and reducing water quality impacts, but their utilization is generally lower than their agricultural counterparts. The goal of this proposed work is to improve water quality planning and implementation through recommendations to improve the overall adoption, penetration and permanence of urban stormwater BMPs. Our research approach blends statistical analysis with social science techniques to determine 1) how many BMPs do we need? and 2) how can we get them in the watershed?

Problem: While agricultural systems have utilized Best Management Practices to reduce pollution for a number of years, work on urban stormwater management is lacking. The West Lafayette-Lafayette communities spanning the banks of the Wabash River in north central Indiana have a combined population of over 215,000 people. Like many similar sized communities across the country, the region is struggling to deal with increasing stormwater impacts on water quality. Improvements to stormwater conveyance and treatment infrastructure alone cannot resolve the problem. Stormwater conservation practices, such as rain gardens, rain barrels and permeable pavement offer the potential of decreasing stormwater volumes and reducing water quality impacts, but their utilization is generally lower than their agricultural counterparts. Poor penetration is attributed to several reasons, including more numerous landowners with less property, a limited number of cost incentive programs and fewer formal public education programs than found in the agricultural community. Secondly, there is little demonstrated ability to show watershed-scale water quality improvement due to BMP implementation in urban environments, which is a function of both the needed intensity of BMP implementation to enact a desired change, as well as the statistical design of a monitoring program that can detect the expected rates of change.

Research Objectives: This project will address the knowledge gap regarding the watershed-scale effectiveness of urban stormwater BMPS, starting with how many BMPs it takes to show statistically significant water quality improvement and extending to the willingness of landowners to adopt. Our specific project objectives include:

1. Evaluate the level of adoption and intensity and duration of sampling needed to demonstrate statistically significant change;
2. Assess the factors influencing practice adoption, penetration and permanence; and
3. Develop watershed management planning strategies for achieving urban water quality goals.

Methodology: Our approach blends statistical analysis and physical modeling to determine the location and level of adoption and monitoring needed to reach water quality targets, with surveys, and practice screening to assess the level of BMP adoption in our urban watersheds, and the penetration and permanence of that adoption, to formulate overall recommendations.

Results:

Objective 1: We have made progress on both tasks during the current project period.

Task 1: Analysis of the effectiveness of monitoring experimental design
These results are based on evaluations of TSS, E.coli, NO_3-N and TP concentration pre- and post-implementation of stormwater best-management practices by the Wabash River Enhancement Corporation (WREC). The single-site t-test results showed statistically significant changes in mean concentrations for NO_3-N in Elliot Ditch (increase of 0.27 mg/l, p=0.00) and Little Wea (decrease of 0.67 mg/l, p=0.00), TSS in Elliot Ditch (increase of 3.69 mg/l, p=0.01), and TP in Little Wea (increase of 0.01 mg/l, p=0.00). Under the paired ANCOVA design, statistically significant changes in concentration was exhibited for NO_3-N in Little Wea Creek (increase of 0.001%) pair and in Elliot Ditch (decrease of 0.002%) relative to Little Pine, TSS in Elliot Ditch (increase of 0.004% relative to Little Pine), and E.coli in Little Wea relative to Little Pine (decrease of 0.001%). Monthly storm volume totals were examined as well. The single site design did not detect any changes in monthly storm volume, however, the paired design method detected significant decreases in volume in both watershed pairs. Elliot Ditch had a decrease of 55.6%, and Little Wea had a 1.78% decline in volume, both relative to Little Pine. The decrease in storm volume could translate to significant reductions in load, even if minor increases in concentration are detected, as was the case for TP load in Little Wea Creek.

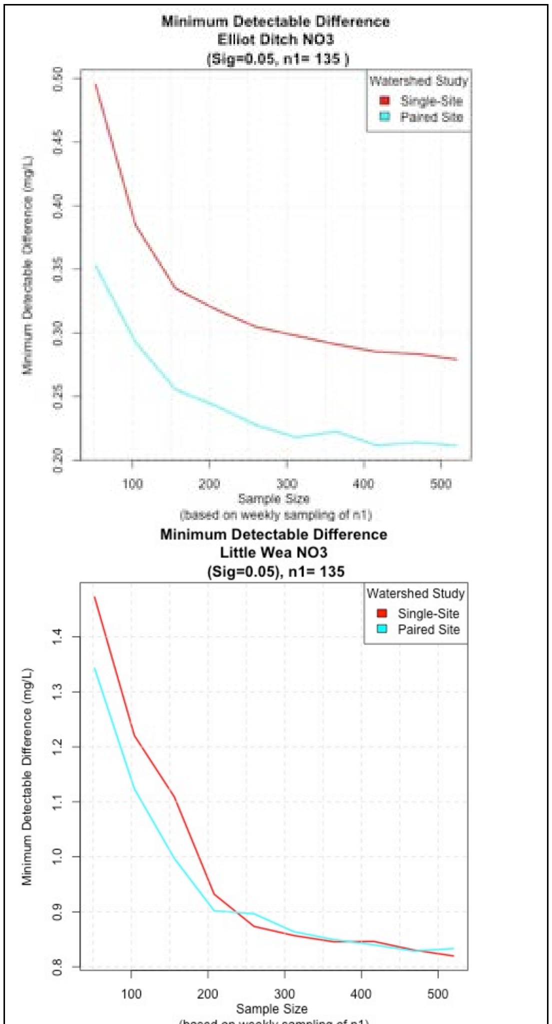

Figure 1. MDD results for NO_3-N in Elliot Ditch and Little Wea.

A Monte Carlo analysis was used generate minimum detectable difference (MDD)curves based on 1000 scenarios matching the mean, standard deviation, and sample size of the data, and an assumed normal distribution for the power analysis. Using the single site t-test suggests that the observed NO_3-N difference in means (approximately 0.3 mg/L) in Elliot Ditch can be confirmed to be statistically significant with a power of 0.8 and significance level of 0.05) with approximately 300 samples collected post-implementation (Figure 1). In contrast, the same observed difference would need 100 samples in each watershed using the paired ANCOVA design. The MDD curves for Little Wea suggest a need for greater than 500 samples under both designs to detect change. The MDD suggested by the power analysis (0.8 mg/l) is above the statistically significant change of 0.67 mg/l detected by the t-test. Possible sources for this discrepancy could be the removal of signal in the data due to deseasonalizing, the fact that the observed data does not confirm to test assumptions, or the power analysis technique. Additional work is being done to isolate the specific sources of discrepancy.

Task 2: Quantifying the required level and location of adoption

Preliminary investigations using the Long-Term Hydrologic Impact Assessment (L-THIA) model started with an evaluation of the efficiency of the model. The 2006 National Land Cover Database (NLCD) was used in this case and 15 different categories of land cover were reclassified to 6 major classes for this project (Table 1).

Table 1: Area of the reclassified land cover based on the 2006 NLCD.

Number	*Type*	*Area in acres*
1	Low Density Residential (LDR)	3716.43
2	High Density Residential (HDR)	2771.93
3	Forest/Wood	284.66
4	Agricultural	4475.69
5	Grass/Pasture	591.57

Simulated runoff from the watershed after implementing known management practices was compared with the observed streamflow data (observed data from USGS streamflow gaging station Elliot Ditch near Elston, IN; period of record - March 19, 2009 to 2015) after separating baseflow from observed streamflow using the Web based Hydrograph Analysis Tool (WHAT). In 2013 the separated runoff (direct runoff) was 5064.92 acre-ft for the USGS 033356725 station. The simulated runoff in the watershed was 4970.46 acre-ft.

Two different options were tried and tested for the preliminary investigations of pollutant load reductions. These are the web-based and python based L-THIA model. Simulated pollutant load reductions were the same for all implemented management practices using the web based L-THIA model. The python based L-THIA model is a more detailed tool designed to evaluate runoff and water quality influences of land use changes and management practices applied at the grid cell level. Therefore, python based L-THIA model, which allows more site specific description of BMPS, will be used in this project.

In addition, the following decisions have been made regarding future model implementation:

- Observed streamflow data for the Elliot Ditch near Elston, IN gaging station is available from March 19, 2009 to present. Therefore, shorter period weather data (2009-2014) will be used instead of long term (30 years) weather data for model revaluation.
- The 2011 NLCD will be used for further modeling purposes instead of 2006 NLCD.
- Management practices will not be implemented in the agricultural land or cover crops land area. The load from these area would be subtracted when calculating the efficiency of the model.
- The road buffer restriction would be removed when implementing bioretention management practices.

Objective 2: Assess factors influencing practice adoption, penetration and permanence

Progress was made with respect to Task 1 during this project period.

In 2014, the Natural Resources and Social Science (NRSS) Lab at Purdue University collaborated with WREC to design an on-site assessment checklist with criteria for evaluating the level of maintenance of rain barrels. The details of this analysis are described in Gao et al. (2016) and summarized briefly here. Each rain barrel received a score from 0 to 3 after completing the assessments. Table 2 displays the criteria to achieve an index score.

Table 2: Rain barrel assessment index

Category Name	Category Index Score	Criteria
Excellent	**3**	Rain barrel installed, fills with water, and is able to be used to its full potential
Acceptable	**2**	Rain barrel installed and does fill with water, but cannot be used to its full potential
Unacceptable	**1**	Rain barrel installed, but does not fill with water
Absent	**0**	Rain barrel not installed

A total of 623 rain barrels were successfully assessed between May 30, 2014 and Oct 6, 2015. Table 3 displays a summary of assessment scores in 2014 and 2015. Notably, 25% and 29% of the rain barrels were absent after two and three years of use. Although the average assessment score in 2015 is higher than that in 2014, the percentage of Full Maintainers (level 3) in 2014 is higher than that in 2015 (67% in 2014; 47% in 2015).

Table 3: Summary of assessment scores

Category	**Index Score**	**Wabash 2014**	**Wabash 2015**
Full Maintainers	Excellent (3)	96 67.10%	226 47.10%
Partial Maintainers	Acceptable (2)	7 4.90%	35 7.30%
	Unacceptable (1)	5 3.50%	81 16.90%
	Absent (0)	35 24.50%	138 28.80%
	Mean	2.15	2.42
	Median	3	3
	Mode	3	3

Comparison between non-adopters, adopters and Full Maintainers:
For the purpose of investigating who is more likely to adopt and maintain their rain barrels, a comparison was made between rain barrel adopters and non-adopters, and between Full Maintainers and Partial Maintainers. The comparison between different groups includes their social demographic profile, their awareness about local water quality issues, their opinion towards the environment, and their constraints and experience about various conservation practices. A sub-set of the overall results are included here:

Social demographic profile:

- More rain barrel adopters and Full Maintainers lived on residential lots of greater than one acre (5.0% non-adopters; 13.3% rain barrel adopters; 9.1% Full Maintainers).
- A higher percentage of rain barrel adopters and Full Maintainers lived on their own property than that of non-adopters (87.7% non-adopters; 97.9% rain barrel adopters; 96.6% Full Maintainers).

Perceptions about water impairments

- Non-adopters are more likely to recognize all the listed water impairments as a problem in their area than rain barrel adopters, except for "sedimentation in the water".
- Among the listed water impairments, non-adopters are significantly different from rain barrel adopters in recognizing "algae" (Sig.= .000. Mean value: 2.77 non-adopters; 2.36 rain barrel adopters) and "not enough oxygen in the water" (Sig.= .003. Mean value: 2.80 non-adopters; 2.40 rain barrel adopters) as a problem.

Perceptions about sources of water pollution

- Rain barrel adopters are more likely to identify most of the listed sources of water pollution as a problem in their area than non-adopters are.
- Among the listed sources of water pollution, rain barrel adopters are significantly different from non-adopters in identifying the following as local problems: "discharges from sewage treatment plants" (Sig.= .028. Mean value: 2.70 non-adopters; 2.92 rain barrel adopters), "soil erosion from shoreline and/or streambanks" (Sig.= .049. Mean value: 2.53 non-adopters; 2.74 rain barrel adopters), "improper disposal of waste, oils, and chemicals into storm drain" (Sig.= .020. Mean value: 2.62 non-adopters; 2.85 rain barrel adopters), "stormwater runoff from rooftops, parking lots, and roads" (Sig.= .002. Mean value: 2.57 non-adopters; 2.86 rain barrel adopters), and "street salt and sand" (Sig.= .018. Mean value: 2.67 non-adopters; 2.88 rain barrel adopters).
- Noticeably, both groups of respondents are less likely to recognize "waste material from pets" as a local problem (Mean value: 2.14 non-adopters; 2.09 rain barrel adopters).

Attitudes towards the environment:

- Full Maintainers are not significantly different from Partial Maintainers in their responses to these statements.

▪ Rain barrel adopters (both Full and Partial Maintainers) have more strongly positive attitudes towards the environment than non-adopters do.

Future Plans:

The NRSS, alongside the WREC, will resurvey the Wabash urban residents in the summer of 2016, to monitor their perceptions, attitudes and behavior change. The survey design will be similar to the 2014 Wabash Urban Resident Survey, with the following added research questions:

- o What are the factors limiting people who received technical assistance from the WREC to apply for the funding of a practice?
- o What are the other ways for people to learn about BMP installation other than the WREC?

Task 2: Understanding Permanence of Urban BMPs and Task 3: Quantifying penetration

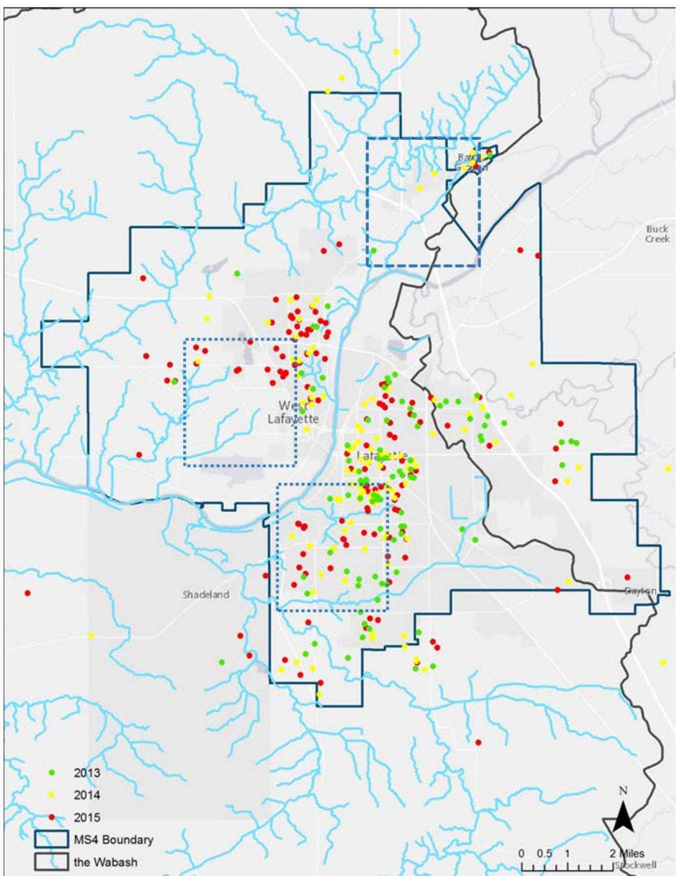

Figure 2: Rain barrel adoption by year.

Work is in the planning phases for these tasks.

The distribution of rain barrels is shown by their purchase date in the Region of Great Bend of the Wabash River watershed in Figure 2:

▪ There was a high convergence of the adoption of rain barrels in the area near the Wabash River in Lafayette in 2013 and 2014.

▪ The adoption of rain barrels increased prominently in West Lafayette in 2015.

▪ There were several rain barrels adopted in the corner of the MS4 boundary in Battle Ground.

The NRSS will select interviewees from representative area of rain barrel adoption and design interview questions asking about their experience with the practice, including their first awareness of the practice, their installation knowledge of the practice, their maintenance issues, and the sharing of their practice with others.

Objective 3: *Development of watershed management planning strategies for achieving urban water quality goals:*

Based on findings from Busse et. al (2015), Gao et. al (2016) and Bentlage (unpublished) we will begin modifying our education and outreach programming in 2016. The following modifications will be incorporated:

- Improve access to the necessary equipment that is needed and contractors that can assist with urban BMP installation. An equipment sharing option will be reviewed with community partners and needs and opportunities for promoting the use of this equipment will be identified.
- Increase awareness of installed practices and individuals that installed the practice. Installed urban BMPs will be promoted via weekly social media posts, installer's experience with urban BMPs will be promoted with monthly blog posts to the www.wabashriver.net blog, highlighted in monthly newsletters, and additional opportunities for individual landowners to host tours and events to promote their urban BMP will be identified.
- Opportunities to convert Detrash the Wabash, Wabash Sampling Blitz, Wabash Riverfest and other volunteers into urban BMP adopters will be identified, prioritized and implemented. Research indicates that individuals that volunteer are interested in the Wabash River and its water quality, thus should be candidates for urban BMP adoption.
- Increase promotion and access to individual one-on-one conservation-based technical assistance.
- Continue to distribute educational Eco-champion signs and track their longevity in comparison with practice maintenance.
- Strategically promote the use of rain barrels to gardeners and those that are interested in reducing the cost of water spent watering flowers and vegetables. Survey results indicate that most rain barrel purchasers installed their rain barrel to reduce the volume and cost of water used in their yard.
- Continue general promotion of rain barrels, native plants and trees as low cost options for increasing property values, improving water quality, and reducing negative impacts on the Wabash River. Specifically, unique uses for these practices, proof that they provide a water quality benefit, identification of ways that all properties support these types of practices.
- Promote the economic benefits of installing urban BMPs through social and traditional media as economic motivators such as water costs and property values are the highest motivators for early adopters.

References

Ahiablame, L., B. Engel, and I. Chaubey, 2012, Representation and evaluation of low impact development practices with L-THIA-LID: An example for site planning. Environment and Pollution, 1(2). Doi:10.5539/ep.v1n2p1.

Engel, B., 2001, L-THIA NPS Long-Term Hydrologic Impact Assessment and Non Point Source Pollutant Model, version 2.1. Purdue University and USEPA.

MD Department of the Environment, 2011, Accounting for stormwater waste load allocations and impervious acres treated, Guidance for National Pollution Discharge Elimination System Stormwater Permits, draft, June 2011.

Major Conclusions and Significance: Since this is an interim project report, the overall major conclusions have not yet been reached.

Publications and Presentations

Gao, Y., N. Babin, A.J. Turner, C.R. Hoffa, S. Peel, and L.S. Prokopy, 2016, Understanding urban-suburban adoption and maintenance of rain barrels, Landscape and Urban Planning http://www.sciencedirect.com/science/article/pii/S0169204616300330.

Gao, Y., 2015, Evaluation of the Adoption, Maintenance and Diffusion of BMPs in Urban and Suburban Landscapes, International Symposium On Society and Resource Management (ISSRM 2015), June 15, 2015.

Grant Submissions: None

Students Three PhD level graduate students are working in this project. Yuling Gao (FNR) is working on the stakeholder interviews and assessment of attitudes, beliefs and other factors influencing the decision to implement and maintain best management practices in urban environments. Fushcia Hoover (ABE) is working on the statistical analysis of water quality data and forecasting of the number of BMPs needed to show change. Sanoar Rahman (AGRY) is working on calculation of load reduction due to BMPs using the Long-Term Hydrologic Impact Assessment-Low Impact Development (LTHIA-LID) model.

Water Quality improvement demonstration effort

Basic Information

Title:	Water Quality improvement demonstration effort
Project Number:	2015IN380B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	IN-004
Research Category:	Water Quality
Focus Category:	Water Quantity, Nutrients, None
Descriptors:	None
Principal Investigators:	Ronald F. Turco

Publication

1. None

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

Title: Water Quality improvement demonstration effort: Antimicrobial resistance in E. coli collected under different flow regimes.

Project type: Research – Demonstration

Project ID: 2015IN380B

Project Duration. March 1, 2015 to February 28, 2016

Congressional District: IN-005

Focus Categories. ECL, GEOMOR, HYDGEO, HYDROL, SED

Keywords. E. coli, Drainage Water, Antibiotic Resistance, Ditch water

Principal Investigators:

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Abstract / Summary:

Streams in our watershed area frequently exceed acceptable levels of *E. coli* set by the State of Indiana (235 CFU per 100mL). In our study area three subwatersheds of the Wabash River are being considered for listing on the State 303(d) list for *E. coli* impairment and recent data indicates that our subwatersheds continue to have significant concentration of *E coli* where numbers can reach 20,000 cfu $100mL^{-1}$ E. coli are commonly used as an indicator of fecal pollution in water. They have been known to transfer antibiotic resistance genes to other bacteria, further complicating the understanding of resistance patterns (Cray et al 2007). This study evaluated the resistance patterns in E. coli within a well-studied watershed, for common veterinary and medical antibiotics. We also evaluated resistance patterns under two flow regimens as prior work had suggested water enters the system from different source depending on flow conditions. Of the high flow isolates, 20% showed no resistance, 31% showed resistance to one antibiotic, and 62% showed resistance to two or more antibiotics. In contrast, 100% of low flow isolates showed resistance to two or more antibiotics. The large difference between sample times suggest that flow and other seasonal conditions play a big role in types of resistant bacteria found in the water.

Problem: Multi-antibiotic resistance is becoming a world-wide problem due to abundant use by veterinarians and medical doctors (Sayah et al 2005). Research has shown that antibiotics can enter waterways though release of human and animal waste in to the environment. This occurs though field application, flooding or discharge from confined animal feeding operations (CAFO) lagoons, or animals allowed direct access to streams (Campagnolo et al 2002). Antibiotics can also enter water through human sources such as waste water treatment plants (Burkholder et al 2007).

E. coli are commonly used as an indicator of fecal pollution in water. They have been known to transfer antibiotic resistance genes to other bacteria, further complicating the understanding of resistance patterns (Cray et al 2007). This study will look at resistance in E. coli of common veterinary and medical antibiotics within a well-studied watershed.

Research Objectives:

- To identify resistant E. coli in a well sampled watershed
- To examine if there are differences in resistant E. coli profiles during times of high and low flow

Methodology:

Design: Antimicrobial resistance in E. coli was to be examined at five locations near Lafayette, Indiana under high and low flow conditions. Three stream sites and two locations on the Wabash River were chosen due to the availability of extensive back ground data and USGS flow gages.

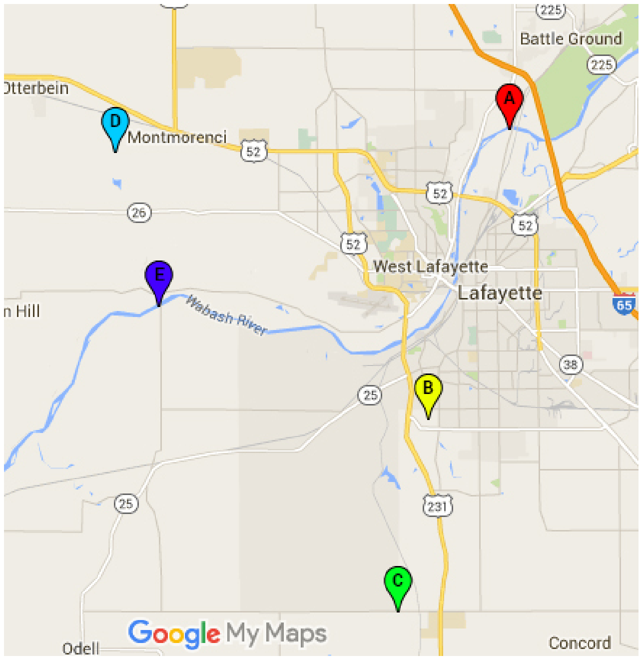

Figure 1. Map of sampling locations. A – Wabash River Upstream (WU), B – Elliot Ditch (ED), C – Little Wea Creek (LW), D – Little Pine Creek (LP), E – Wabash River Downstream (WD)

Sampling: Each site was sampled twice; once during a high flow event in the spring and once during a low flow period in the late summer. Samples were taken using sterile 1L bottles at four to six inches of depth in the deepest part of the stream.

E. coli Isolation: Two methods were used to isolate E. coli. For the first method, 100mL of stream water was filtered through a 0.45um filter. The filter was placed on a mTEC agar plate and incubated for 18-24 hours at 44.5^{o}C. At the end of the incubation period, filters were placed on a pad saturated with a urea solution (2g urea + 10mg phenol red per 100mL water) for 20 minutes. Individual yellow or yellow-brown colonies were picked off and streaked on EMB agar.

For the second plates, 100mL of water was used for enumeration of E. coli using the IDEXX Colilert method. Once counts were obtained, the back side of the trays were wiped with ethanol. A sterile needle and syringe was used to pierce one of the wells. One to two drops of liquid was streaked onto EMB agar plates. This was repeated for each well until a total of 25 plates were made. Each well was considered a separate isolate. For both methods, EMB agar plates were incubated overnight at 44.5^{o}C. Colonies showing a green sheen were considered to be E. coli. Transfers continued to fresh plates until only E. coli remained on the plates. Once a pure culture was grown, a colony was streaked onto LB agar, grown overnight at 35^{o}C, then placed in a refrigerator until further testing could occur.

Each isolate was tested for E. coli using the standard methods for Simmons Citrate and Indole. If either of the two methods tested negative for E. coli, the isolate was discarded. All E. coli isolates testing positive were used for antimicrobial analysis.

Antimicrobial Testing: The Kirby-Bauer disc diffusion method for antimicrobial testing was used for analysis of each isolate (Bauer et. al. 1966). Testing was completed using BD Sensi-discs. Twelve antibiotics were chosen. Two plates for each isolate were inoculated. Six of the sensi-discs were placed on each plate. The following antibiotics and concentrations were used: Ampicillin - AMP (10ug), Amoxicillin – clavulanic acid - AUG (20/10ug), Ceftriaxone - AXO(30ug), Cefoxitin - FOX (30ug), Gentamicin – GEN (10ug), Streptomycin – STR (10ug), Tetracycline – TET (30ug), Ciprofoxacin - CIP (5ug), Nalidixic Acid – NAL (30ug), Trimethoprim – Sulfamethoxazole – SXT (1.25/23.75ug), Sulfisoxazole – FIS (250ug), Chloramphenicol – CHL (30ug). All antibiotics were purchased from BD in their Sensi-disc susceptibility disc form. Zone diameters were recorded and the data was normalized using CLSI interpretive criteria (CLSI 2013). Each isolate/antibiotic pair was categorized as susceptible, intermediate or resistant. For the purpose of this study, any isolate falling into the intermediate or resistant category was considered to show signs of resistance to that particular antibiotic. These two categories were combined to a single "resistant" category.

Cluster Analysis: Cluster analysis was completed with normalized data using JMP.

Results and Significance

For most of the parameters analyzed, high flow samples were higher than the low flow samples. Exceptions include the following: WU E. coli, ED Nitrate + Nitrite, and LP Total Phosphorus.

Table 1. A summary of common water quality parameters for each site taken at the time of sampling. Each parameter is split in to high and low flow, referring to the conditions when sampling occurred.

	Flow (cfs)		**E. coli (MPN/100mL)**		**Total Suspended Solids (mg/L)**		**Nitrate + Nitrite (mg/L)**		**Total Phosphorus (mg/L)**	
	High	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**
WU	6453.6	2656.8	46.5	52.9	15.6	12.5	3.284	1.018	0.019	0
WD	6657.3	2761.9	461.1	23.5	152.0	19.3	3.299	1.600	0.078	0
LW	90.0	6.3	1986.3	648.8	964.0	5.1	5.945	1.974	0.513	0
LP	8.4	1.3	613.0	435.2	12.6	9.0	4.372	1.842	0.016	0.134
ED	20.0	8.0	3645.0	920.8	132.0	3.7	0.491	0.725	0.060	0.023

E. coli isolates show resistance to all antibiotics except for gentamicin (Figure 2). During low flow conditions, all E. coli were resistant to sulfasoxazole. More than 50% of E. coli isolates from low flow conditions were resistant to chloramphenicol, sulfasoxazole, trimethoprim-sulfamethoxazole, ampicillin, and streptomycin. Less than half of high flow isolates showed resistance for all antibiotics. Low flow isolates showed higher resistance to all antibiotics than high flow isolates.

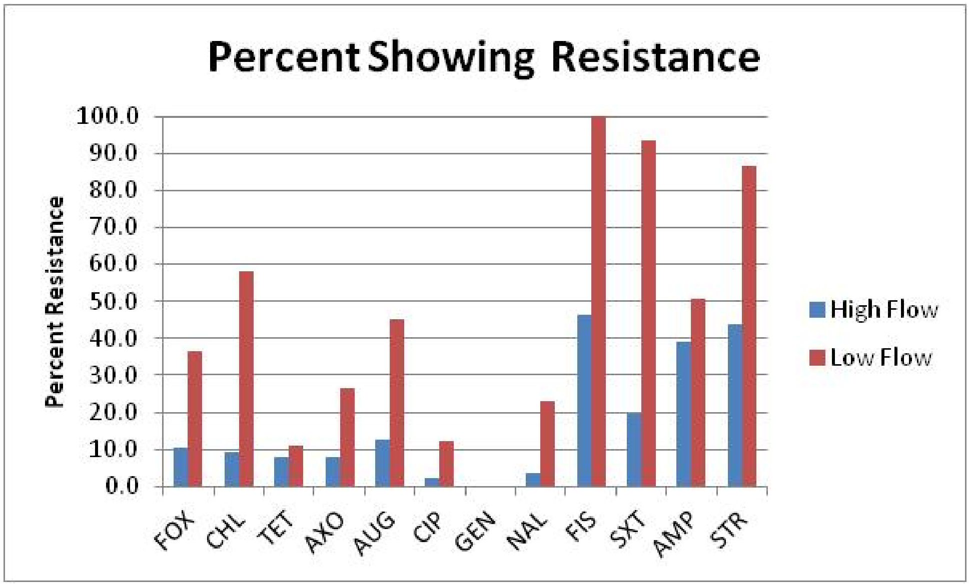

Figure 2. Percent of isolates from each sample event showing resistance to each antibiotic.

Antimicrobial Resistance Index (ARI) was calculated using the following formula (Webster et. al. 2004):

ARI = (number of isolate/antibiotic tests showing resistance for a site) / (total number of tests for each site)

There is higher resistance under low flow conditions for all sites. Highest resistance occurred at Little Pine during low flow conditions and the downstream Wabash site under high flow conditions. Little Pine also showed the most extreme difference in resistance between high and low flow. In general, there was higher resistance at the downstream Wabash site than at the upstream site.

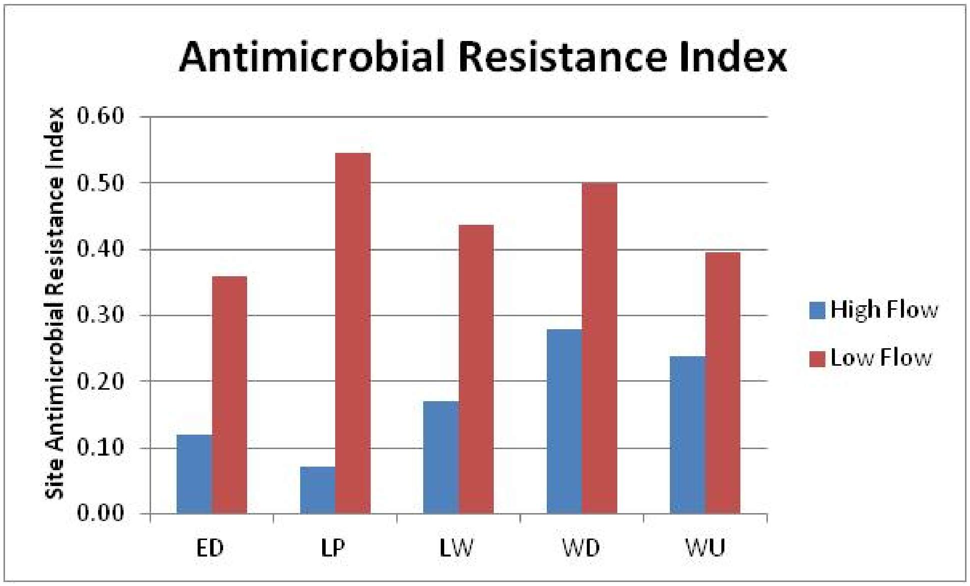

Figure 3. Antimicrobial resistance index for each of the five sample sites.

Cluster analysis on all isolates shows that, in general, there is separation between high and low flow isolates (Appendix A, Figure 1). This is also true when comparing isolates within a single stream (Appendix A, Figure 4). When comparing all high flow isolates, there is some tendency to group according to stream site, but the correlation is less strong (Appendix A, Figure 2). The same holds true during low flow conditions (Appendix A, Figure 3).

Major Conclusions:

Of the high flow isolates, 20% showed no resistance, 31% showed resistance to one antibiotic, and 62% showed resistance to two or more antibiotics. In contrast, 100% of low flow isolates showed resistance to two or more antibiotics. The large difference between sample times suggest that flow and other seasonal conditions play a big role in types of resistance found in the water. Hu, et. al. (2008) examined resistance in E. coli during summer and winter months. They found no difference in the occurrence of resistance between sample events. However, it is not clear if flows were different at each event.

Of the antimicrobials tested, high flow and low flow isolates were most commonly resistant to sulfasoxazole (46% and 100% respectively). High flow isolates were commonly resistant to streptomycin and ampicilln (44%, 39%). Low flow isolates were commonly resistant to trimethoprim/sulfamethoxazole and streptomycin (93%, 87%). In their research, Like this study, Hu, et. al (2008) found E. coli to most commonly be resistant to sulfanimides and ampicillin.

There were more E. coli present in the streams during high flow, but a much lower percentage of the isolates were resistant. This suggests that there may be a larger variety of E. coli genotypes during high flow events when compared to low flow. Having more variety of genotypes would allow for a larger number of E. coli that were not resistant to the antibiotics tested. This may also indicate that there are more sources of contamination during high flow events. Further studies are needed to work out the reasoning behind these results.

Publications

None yet

Students

Undergraduate students assisted with the preparation of media for isolation and growth of E. coli isolates.

Graduate Students:/Undergraduate Students: 0:3

References

Bauer, A.W.; Kirby, W.M.; Sherris, J.C.; Turck, M. 1966. Antibiotic susceptibility testing by a standardized single disk method. American Journal of Clinical Pathology. 45 (4).

Burkholder, J., B. Libra, P. Weyer, S. Heathcote, D. Kolpin, P.S. Thorne, and M. Wichman. 2007. Animal feeding operations on water quality. Environmental Health Perspectives. 115: 308-312.

Campagnolo, E. R., K. R. Johnson, A. Karpati, C.S. Rubin, D.W. Kolpin, M.T. Meyer, J.E. Esteban, R.W. Currier, K. Smith, K.M. Thu, and M. McGeehin. 2002. Antimicrobial Residues in animal waste and water resources proximal to large scale swine and poultry feeding operations. Science of the Total Environmnet. 299: 89-95.

Clinical and Laboratory Standards Institute (CLSI). 2013. M100-S23 Performance Standards for Antimicrobial Susceptibility Testing; Twenty-Third Informational Supplement.

Cray, P.J., Anandaraman, N., and Plumblee, J. 2007. Perspective on antimicrobial susceptibility of Escherichia coli isolates recovered from poultry carcass rinsates as part of the animal arm of NARMS. National Foundation for Infectious Disease. 56: 39-40.

Hu, J.; Shi, J.; Chang, H.; Li, D.; Yang, M.; Kamagata, Y. 2008. Phenotyping and genotyping of antibiotic-resistant *Escherichia coli* isolated from a natural river basin. Environmental Science and Technology. 42, 3415-3420.

McKean, D.M.; Calabrese, J.P.; Bissonnette, G.K. 1995. Antibiotic resistant gram-negative bacteria in rural groundwater supplies. Water Research. 29 (8), 1902-1908.

Sayah, R. S., J. B. Kaneene, Y. Johnson, and R. Miller. 2005. Patterns of antimicrobial resistance observed in *Escherichia coli* isolates obtained from domestic- and wild-animal fecal samples, human septage, and surface water. Applied and Environmental Microbiology. 71: 1394-1404.

Servais, P.; Passerat, J. 2009. Antimicrobial resistance of fecal bacteria in waters of the Seine river watershed (France). Science of the Total Environment. 408 (2), 365-372.

Webster, L.F.; Thompson, B.C.; Fulton, M.H.; Chestnut, D.E.; Van Dolah, R.F. 2004. Identification of sources of Escherichia coli in South Carolina estuaries using antibiotic resistance analysis. Journal of Experimental Marine Biology and Ecology. 298, 179-195.

Appendix A: Cluster Analysis

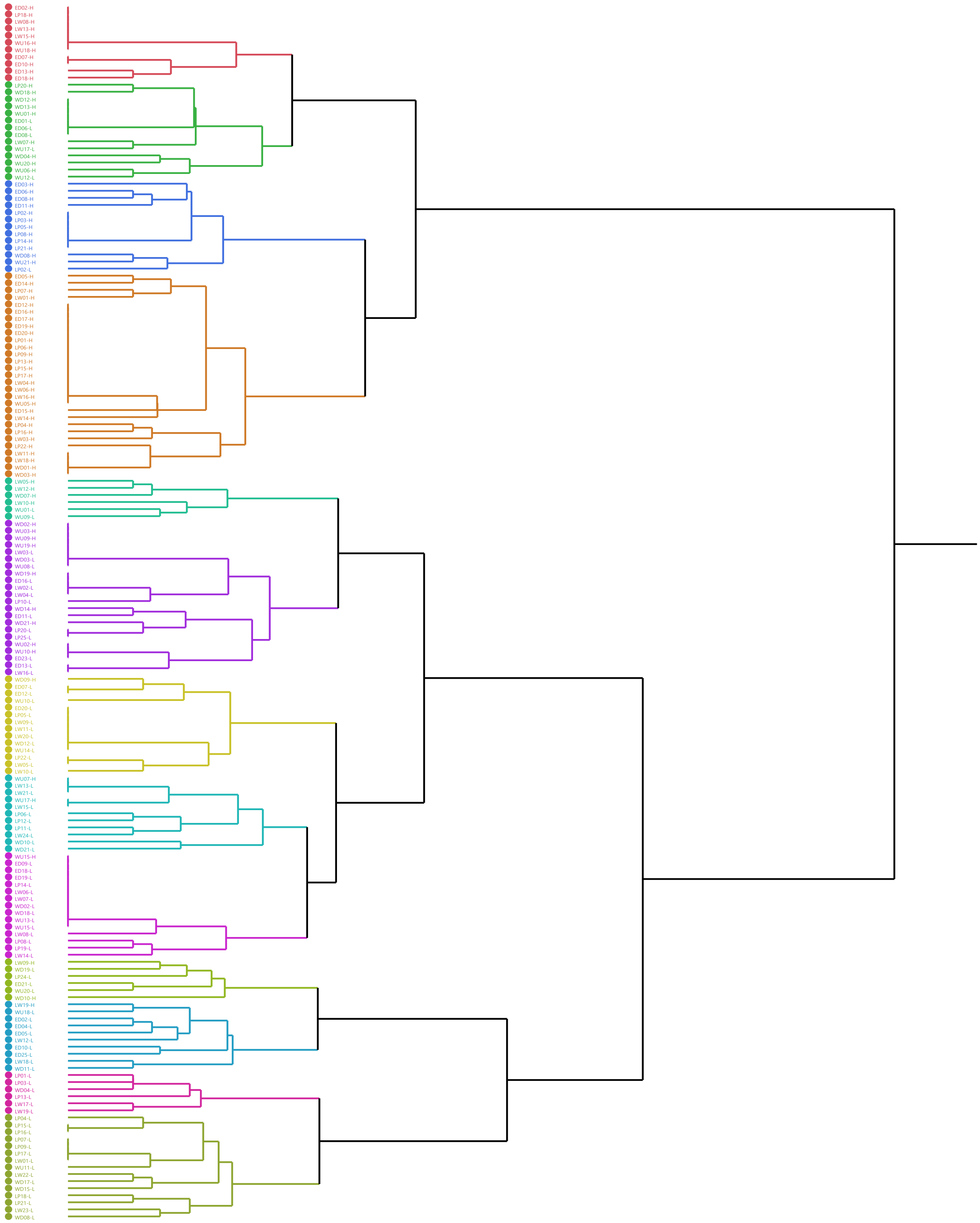

Figure 1. Cluster analysis of all isolates.

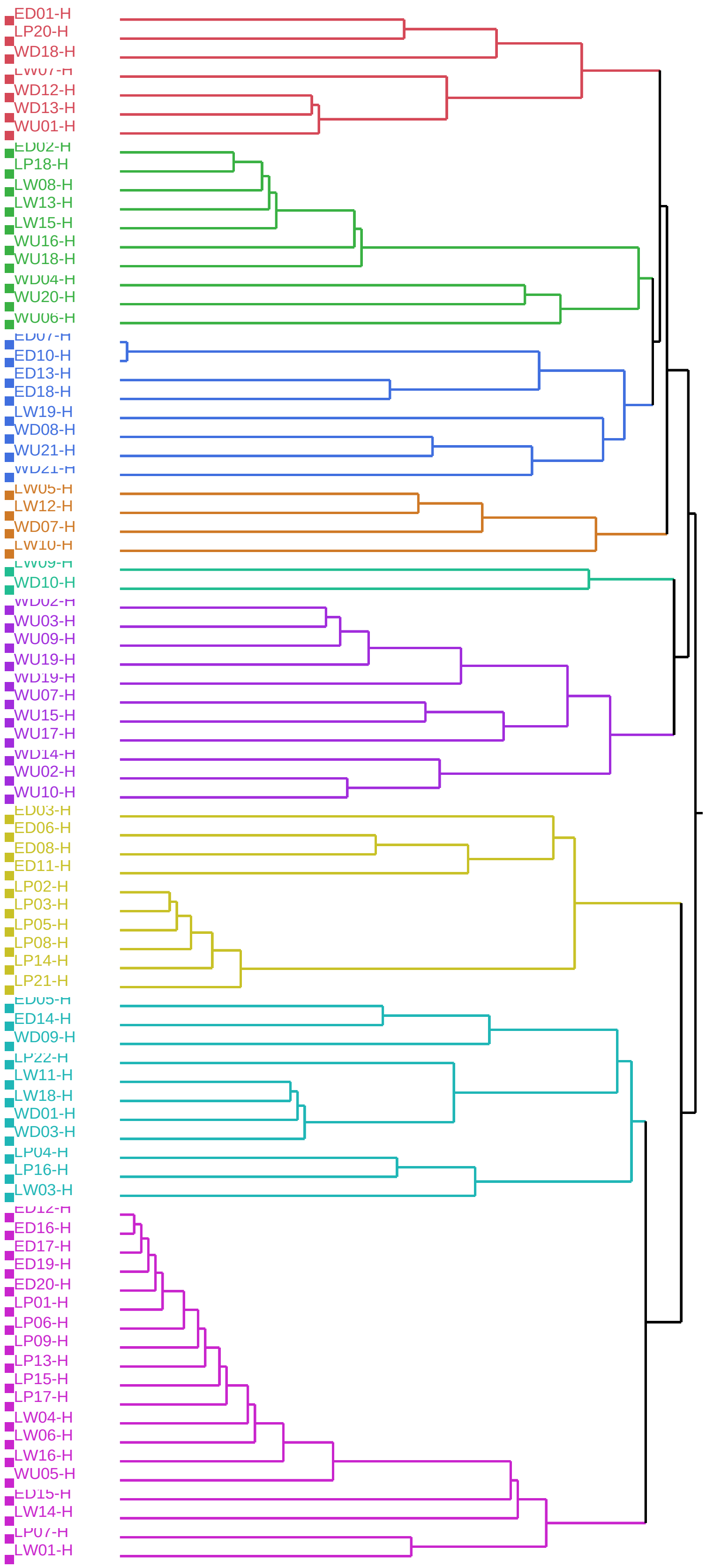

Figure 2. Cluster analysis of all high flow isolates.

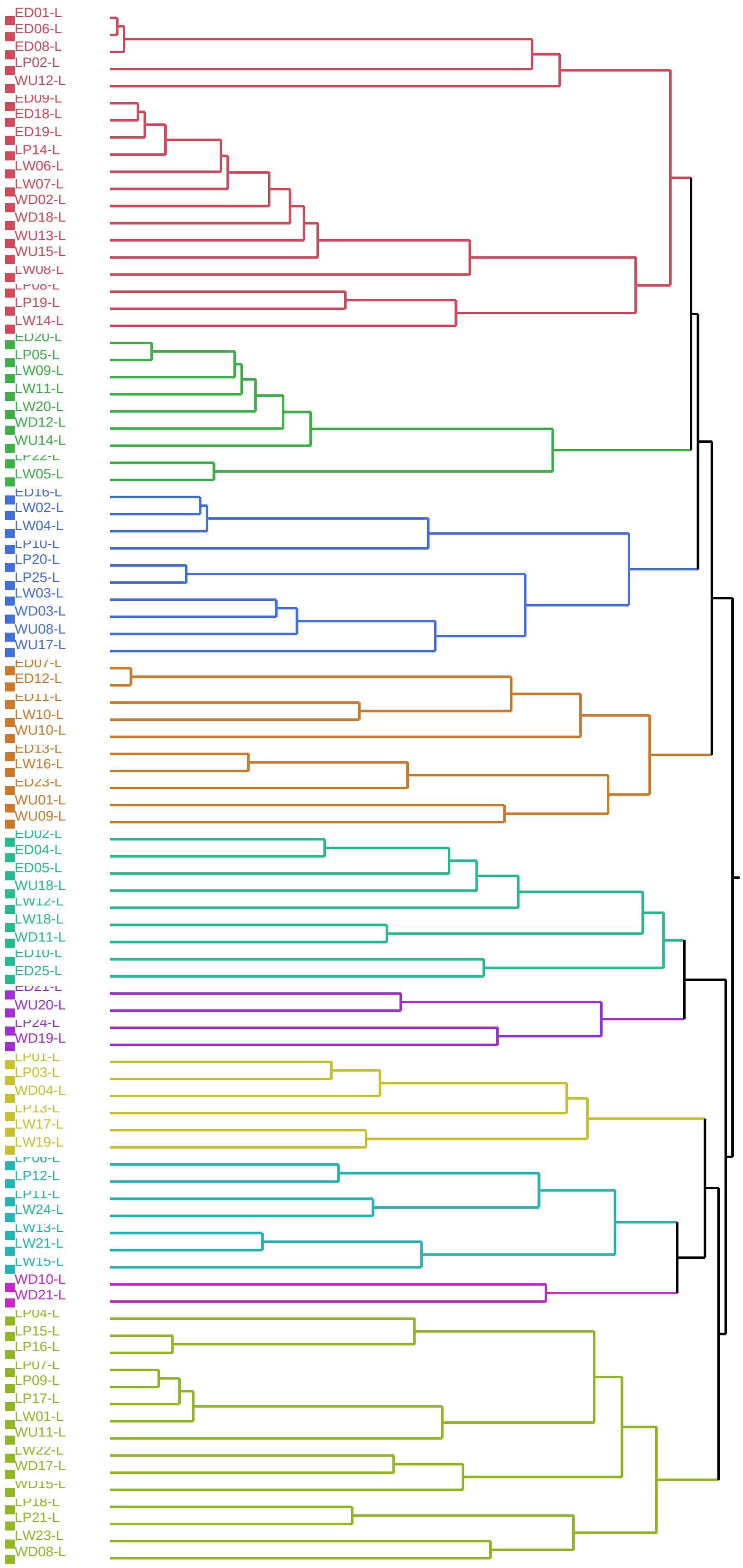

Figure 3. Cluster analysis of all low flow isolates.

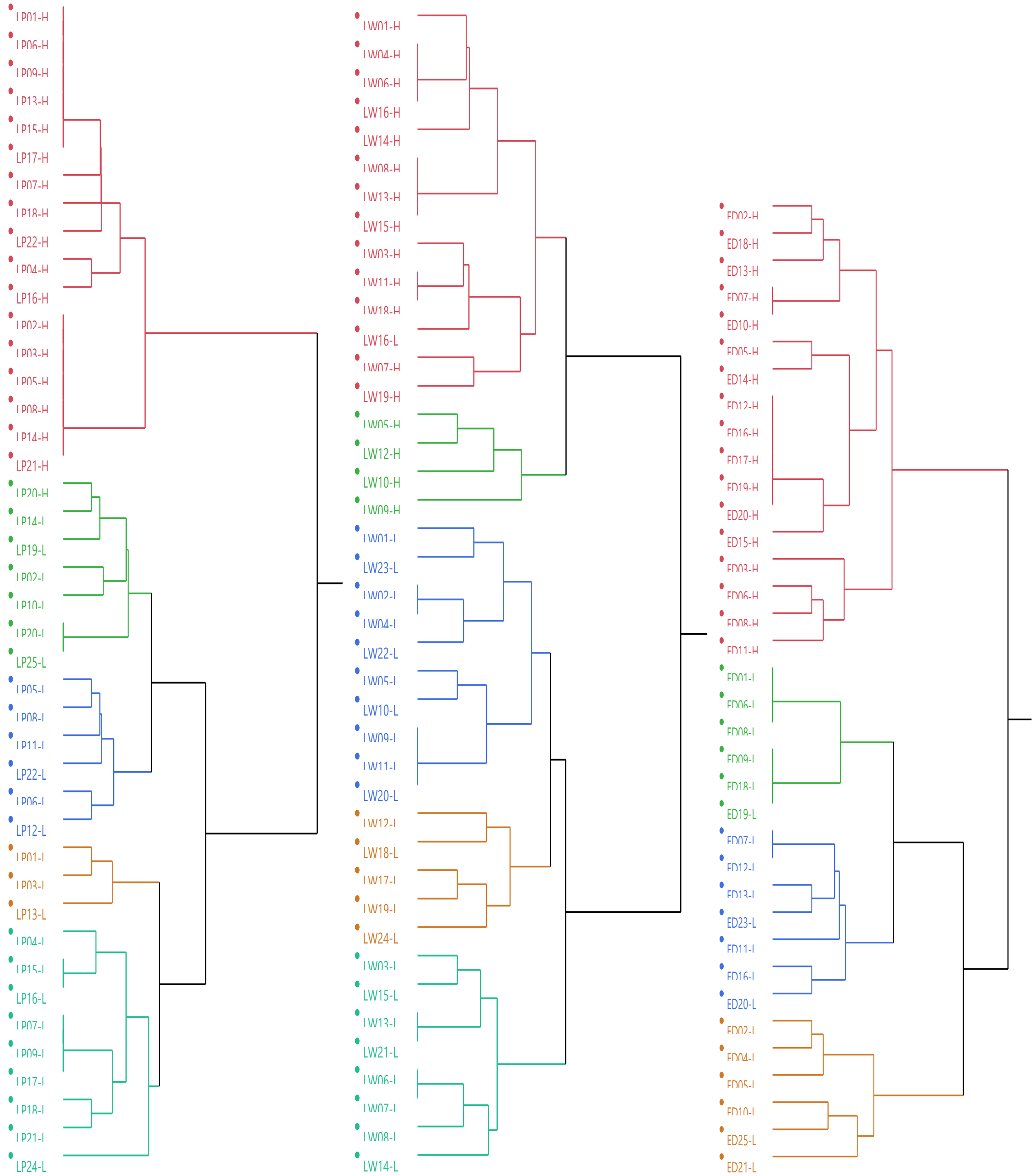

Figure 4. Cluster analysis of high and low flow isolates for each stream site: Little Pine, Little Wea, and Elliot Ditch.

What Is the Source of Baseflow in the Wabash River Watershed?

Basic Information

Title:	What Is the Source of Baseflow in the Wabash River Watershed?
Project Number:	2015IN381B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	IN-004
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Surface Water, Hydrology
Descriptors:	None
Principal Investigators:	Marty D Frisbee, Indrajeet Chaubey

Publication

1. None

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

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Project Type: Research

Project Id: 2015IN381B

Period: March 1, 2015 – February 28, 2016

Congressional District: IN-004

Focus Categories: GW, SW, HYDROL, GEOCHE, AG, WQN, WQL

Keywords: groundwater/surface-water interactions, baseflow, geochemistry,

environmental tracer, radon-222, tile-drainage, source partitioning

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Abstract / Summary:

Tile-drainage systems installed in agricultural watersheds in the Midwestern United States modify natural infiltration, percolation, and recharge processes and as a consequence, substantially change the distribution of groundwater flowpaths discharging to streams draining these watersheds. Topography-driven flow (Tothian flow) is a benchmark conceptual model for groundwater flow and groundwater/surface-water interactions in many different landscapes, ranging from prairies with low topographic relief to mountainous watersheds with high topographic relief. Groundwater flowpaths and flowpath lengths in a Tothian system will scale from local- (short distance from recharge to discharge; short residence times), intermediate-, and regional-scale (long distance from recharge to discharge; long residence times). Thus, in an undisturbed system, a distribution of local- to regional-scale groundwater flowpaths will be discharged to a stream. However, in agricultural watersheds of the Midwest, the water tables are commonly high and tile-drainage systems are installed to drain excess water quickly from the soil to enhance crop yields. These drainage systems route the excess water to a nearby ditch or stream much quicker than natural drainage. Streamflow in tile-drained watersheds may be largely, if not completely, composed of flow from tile-drainage systems. It remains unclear how tile-drainage practices have impacted intermediate- to regional-scale groundwater flowpaths and the discharge of these flowpaths to streams. This project seeks to address this knowledge gap by conducting synoptic sampling along the main channel of the Wabash River and its major tributaries to identify the presence of and quantify the magnitude of groundwater discharge to streams. Water samples were analyzed for general chemistry, radon-222 (^{222}Rn), and tritium (^{3}H). Other tracers such as chlorofluorocarbons (CFCs) and/or chlorine-36 (^{36}Cl) were also used to identify and age-date groundwater components. Our study found evidence for “older” groundwater with residence times ranging up to 65 years in small catchments draining to the Wabash River and Sugar Creek. This groundwater plays a significant role in streamflow and baseflow generation in these small catchments. However, due to widespread flooding conditions in the Wabash River during the summer and fall of 2015, all stream sites on the Wabash River and the majority of its tributaries were flowing higher than normal. Thus, it remains unclear if these components are

present in baseflow in the Wabash River and if so, where these components are discharged.

Problem:

The Wabash River drains over 2/3 of the state of Indiana and has a watershed drainage area of 85,340 km^2. Approximately 65 percent of the watershed is row-crop agriculture (Pyron and Neumann, 2008) and a significant proportion of that farmland is tile-drained, primarily in the northern till plains. It is important to quantify the impact of tile-drainage on groundwater/surface-water interactions in the watershed given the increasing concern about water quality, ecosystem integrity, and even water quantity during baseflow and times of drought (USACE, 2011). Tile-drainage systems have the potential to: 1) reduce deep percolation and groundwater recharge, 2) disrupt the natural flowpath distributions discharging to streams, 3) increase flashiness of ditches and streams in which they drain, 4) increase sediment, solute, and nutrient yields to ditches and streams in which they drain, 5) increase the magnitude and flashiness of the thermal regime of ditches and streams in which they drain, and 6) alter the ecosystem functioning of streams draining these watersheds. Groundwater is the primary, often exclusive, source of baseflow in more “pristine” watersheds and offers the ability to moderate fluctuations in stream discharge, stream temperature, and chemical composition (Frisbee et al., 2011, 2012).

This project will test two competing conceptual models: 1) Tile-drainage has significantly reduced groundwater recharge and as a consequence, baseflow in the Wabash River and its major tributaries is largely comprised of flow from tile-drainage and contains little, if any, groundwater; and 2) Tile-drainage has likely impacted groundwater flowpath distributions by increasing the proportion of short flowpaths and greatly reducing intermediate-scale flowpaths, yet regional-scale groundwater is present and detectable in baseflow. In summary, what is the source of baseflow in the Wabash River watershed?

Research Objectives:

Two primary objectives are:

1) Determine if groundwater is being discharged to streams in the Wabash River watershed,

2) Determine the fraction of groundwater that is being discharged to streams in the Wabash River watershed. If groundwater is not detected, then objective 2 is not necessary.

Methodology:

Samples of stream water, subsurface runoff (tile-drain/soil-water proxy), groundwater from springs, and precipitation were collected and analyzed for ^{222}Rn. Precipitation samples serve as benchmarks which can be compared to other water samples. Precipitation should have no ^{222}Rn, high tritium concentrations (5 to 15 TU), and be relatively chemically dilute. Samples of water from subsurface runoff through till (serve as tile-drainage proxies where necessary) will likely have no ^{222}Rn, and tritium concentrations reflecting modern precipitation and short residence times (i.e., similar to those concentrations in precipitation). However, subsurface runoff should be more geochemically evolved and enriched in nutrients than precipitation or surface runoff. If ^{222}Rn is present in stream water, then it indicates that groundwater is also present. This is a strong first analytical test.

Samples of precipitation, stream, spring, and subsurface runoff water were then analyzed for general chemistry, ^{222}Rn, tritium, CFC (springs only), and ^{36}Cl analyses. Precipitation was collected using PVC-pipe type collectors deployed at a residence in West Lafayette, IN. The precipitation was assumed to be similar to that falling elsewhere in the watershed. Stream and spring water samples were collected and field-filtered using a peristaltic pump. Addition filtration was completed in the lab as necessary. The inflow tubing was placed as close to the streambed as possible in order to avoid the diffusion of ^{222}Rn in the water column. In addition, water sampling sites were chosen away from rapids and other sources of turbulent flow to prevent loss of ^{222}Rn. Tritium, CFCs, and/or ^{36}Cl samples were collected at the same time and location as ^{222}Rn. Where possible, samples of water from subsurface runoff through till and surface runoff were collected to expand the dataset.

In order to quantify how ^{222}Rn is produced in the local soil and rock, small samples of glacial till, sandstone, and shale from rocks were collected from Shades State Park. The samples were taken back to the lab where the rock leaching and ^{222}Rn in-growth experiment was started. The experiment was designed to take place over the course of 4 weeks and samples were analyzed at the end of each week. For each rock type, we measured 100 grams of 8 samples (2 rock samples were analyzed per each week). This provided 2 shale samples for week 1, 2 shale samples for week 2, etc. This was repeated for the glacial till and sandstone. The individual rock samples were placed in a glass jar, the jar was filled with de-ionized water, and the jar was sealed and taped closed. At the end of each week, we pulled out 2 shale samples, 2 sandstone samples, and 2 till samples for ^{222}Rn analyses.

Results:

The summer and fall of 2015 experienced higher than normal rainfall and widespread flooding along the Wabash River. Attempts to sample baseflow in the Wabash River were delayed until late October and mid-November of 2015. Higher than normal rainfall (> 70 percent above normal) was recorded during June and July (Figure 1) leading to continuous flooding. Flood waters did not begin to recede until late August 2015 and the flood recession was interrupted by higher than normal rainfall in September leading to widespread flooding in the watershed. Flood waters were still receding in October and November when sampling commenced and unfortunately, the measured discharge at the stream sampling sites were running 10 to 450 percent higher than normal for that time of the year. In order to avoid missing an entire sampling season, summer research efforts were shifted to smaller tributary catchments draining into Sugar Creek (a large tributary of the Wabash River) and into the Wabash itself. The smaller catchments were not continuously flooding. This provided an opportunity to determine if groundwater was present in the smaller catchments and to gain insight into the magnitude and residence times of groundwater that may be present in the larger Wabash River.

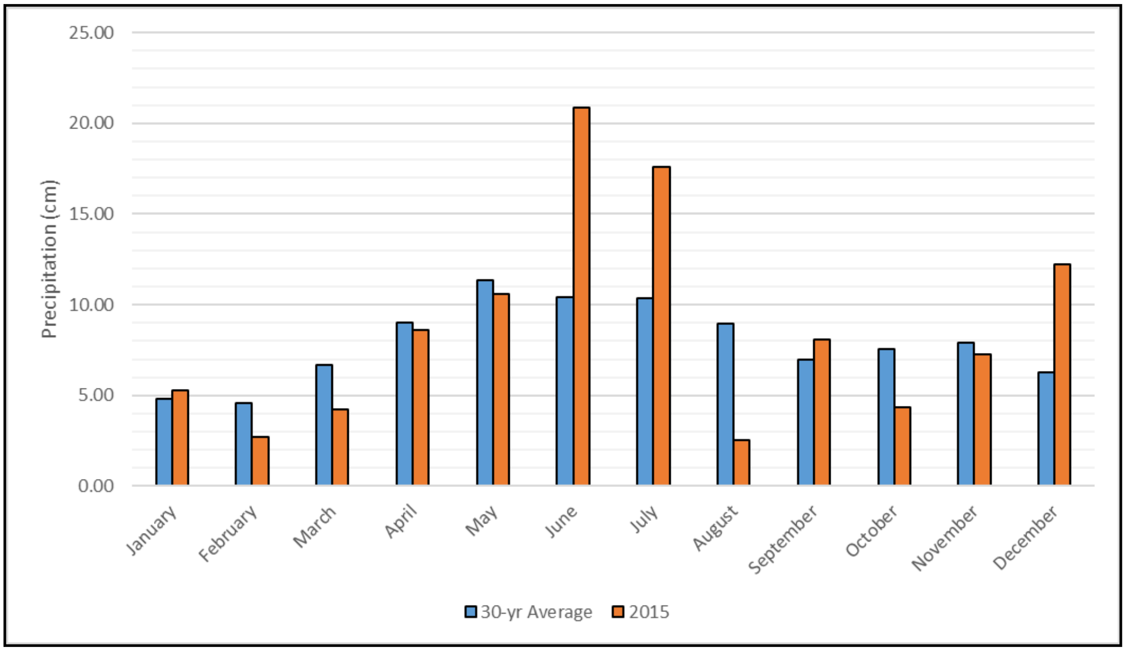

Figure 1: Average total monthly rainfall for West Lafayette, IN averaged over 30 years (blue bars) and total monthly rainfall for 2015 (orange bars).

Data Source: https://www.ncdc.noaa.gov/cdo-web/.

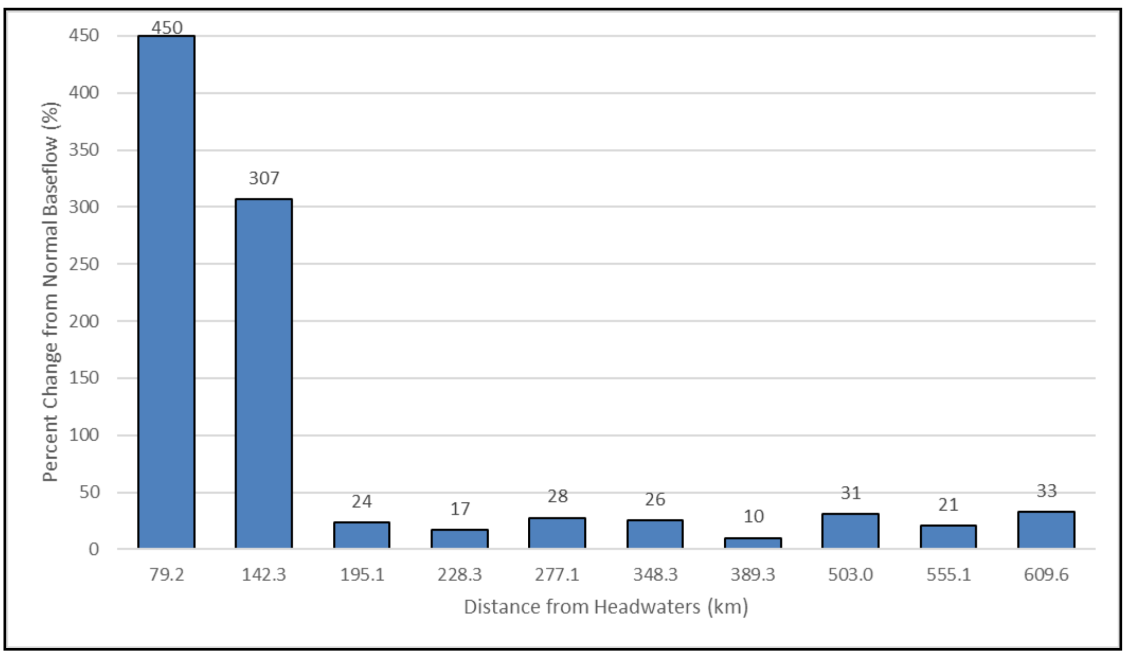

Figure 2: Percent change in baseflow compared to normal baseflow at Wabash River sampling sites in 2015. Distance is measured from headwaters in Fort Recovery, OH.

Data Source: http://waterdata.usgs.gov/in/nwis/rt.

Five small catchments were identified for investigation. These included 2 streams at Ross Hills Park located west of West Lafayette, IN. These short, steep drainages flow into the Wabash River and drain wooded catchments adjacent to agricultural land and a golf course. The other 3 streams drain Shades State Park located near Crawfordsville, IN. These short, steep drainages flow into Sugar Creek and drain wooded catchments adjacent to agricultural land. The geological setting at Shades State Park is described as: 1) an upper layer of alternating clay- and gravel-rich glacial till of variable thickness, 2) an ~ 80 ft thick poorly lithified, Pennsylvanian aged sandstone (Mansfield Formation) containing interbedded iron-rich layers, and 3) a lower thick Mississippian aged shale (Borden Group) which is overcapped in places with a thin layer of younger limestone (Figure 3). The sandstone and shale both exhibit vertical fracturing associated with faulting and the upper shale contains a relatively thick sequence of horizontal-bedding fractures. Faulting and fractures were likely created from the effects of glacial unloading on the underlying geologic strata. The streams at Shades State Park have incised through the sandstone and into the underlying shale. In comparison, the streams at Ross Hills have incised through a thick sequence of till and flow through the upper portion of the Mansfield sandstone which is also poorly lithified in these catchments. Shale does not outcrop at Ross Hills.

Figure 3: Geologic setting of Shades State Park: 1) the glacial till layer is located on top, 2) the buff-colored Mansfield sandstone in the middle is a cliff-forming unit with prominent vertical and horizontal fracturing, and 3) the grey-colored Borden shale is a slope former where the horizontal-bedding fractures are present and appears to be a cliff-former at depth with vertical fracturing throughout the unit.

Radon-222 was detected in 4 of the streams (^{222}Rn was not analyzed in one of the Shades streams; Figures 4,5). At Shades State Park, the ^{222}Rn was exceptionally high for such small streams. The perennial portion of stream 1 begins at a perennial contact spring located in the headcut of Devil's Punchbowl Trail. This spring has a ^{222}Rn concentration of 132 +/- 15 pCi/L that is representative of groundwater. Two other large springs provide flow to the stream. One spring is located between sites 1 and 2. This spring flows from the sandstone unit and has a ^{222}Rn concentration of 389 +/- 18 pCi/L. The second spring is located between sites 2 and 3, flows from the sandstone/shale contact, and has a ^{222}Rn concentration of 600 +/- 28 pCi/L. Two relatively diffuse seepage faces are located between sites 3 and 4, but the flow is too diffuse to get accurate ^{222}Rn measurements. One seepage face occurs at the sandstone/shale contact and the other emerges from the parallel-bedding fractures of the shale unit. Both streams flow over shale near their confluence with Sugar Creek. The ^{222}Rn concentrations in stream 1 reflect the changes in ^{222}Rn observed in the springs (Figure 4). Since ^{222}Rn has a tendency to degas quickly from thin and/or turbulent surface-water bodies, the presence of high concentrations of ^{222}Rn I these streams provides strong evidence for groundwater discharge to the stream (Figure 4). In comparison, stream 2 sites exhibit lower, but stable ^{222}Rn concentrations. Stream 2 has a steeper gradient, and the stream becomes wider and thinner near it's confluence with Sugar Creek. These factors likely increase the possibility of ^{222}Rn degassing and explain the lower ^{222}Rn measured in stream 2. In any case, these concentrations are still higher than expected for such small streams and provide additional evidence for groundwater discharge to the streams at Shades State Park.

Both catchments at Ross Hills are wooded, however, stream 1 drains the Ross Hills Preserve adjacent to a gold course and stream 2 drains agricultural land. Numerous perennial seeps and springs are also present in both catchments. Many perennial springs emerge at the toe of the slope where it meets the modern floodplain of the Wabash River. These springs appear to flow from sandstone. Seasonally intermittent seepage faces were observed flowing from the overlying gravelly intertill layers following snowmelt in March 2015 and again during the rainy summer of 2015. These seeps were chemically distinct from surface runoff and local springs and are likely similar to tile-drainage water.

Large drainage pipes empty into stream 2 and are not present in stream 1. Radon-222 concentrations were also higher than expected and similar to those measured in stream 2 at Shades State Park. However, the ^{222}Rn concentrations of stream 2 were much lower than stream 1 and both streams at Shades State Park (Figure 5). This may represent the discharge of short-residence time groundwater which has not been in the subsurface long enough to attain a higher ^{222}Rn concentration at the time of secular equilibrium. Or, alternatively, it could represent the impact of higher proportions of tile-drainage water discharged to the stream which effectively overwhelms the groundwater component. PCA analyses on the geochemical data for both streams indicated that stream 2 was very similar to the geochemistry of the intermittent, intertill seepage faces (a proxy for til-drainage/soil-moisture), while stream 1 was more similar to local springs. This suggests that tile-drainage may impact stream 2, but it doesn't impact stream 1 or at least not to the same extent that it does stream 1.

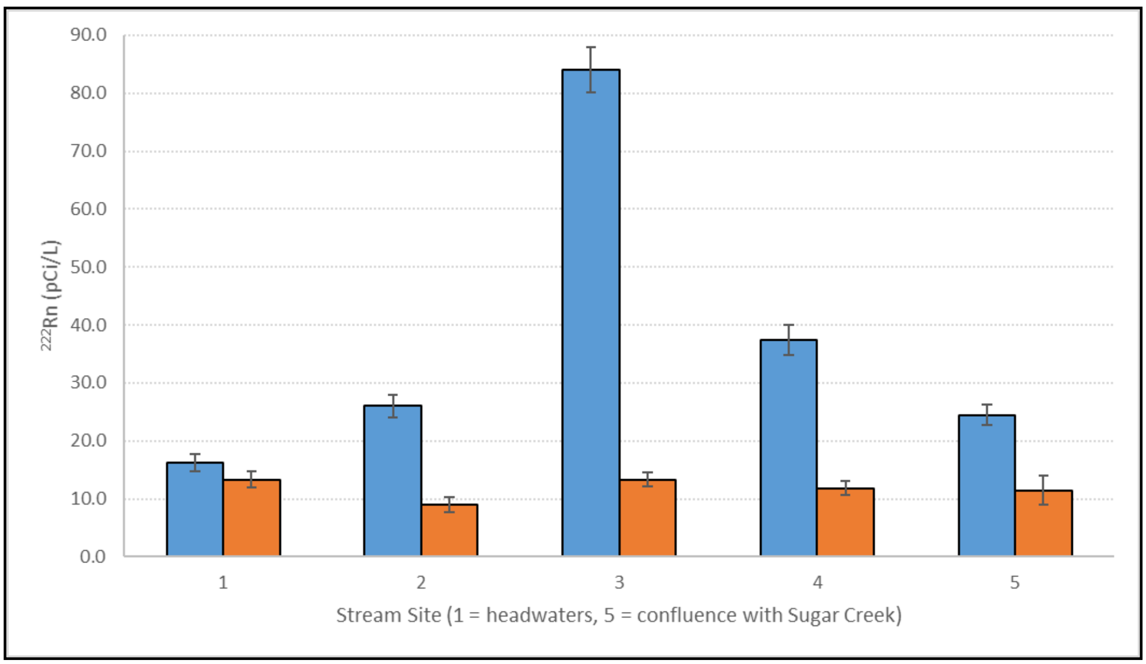

Figure 4: ^{222}Rn concentrations measured in streamflow at Shades State Park. Stream 1 (blue bars) drains the Devil's Punchbowl Trail and Stream 2 (orange bars) drains the Kintz Ravine Trail (samples shown were collected in September 2015).

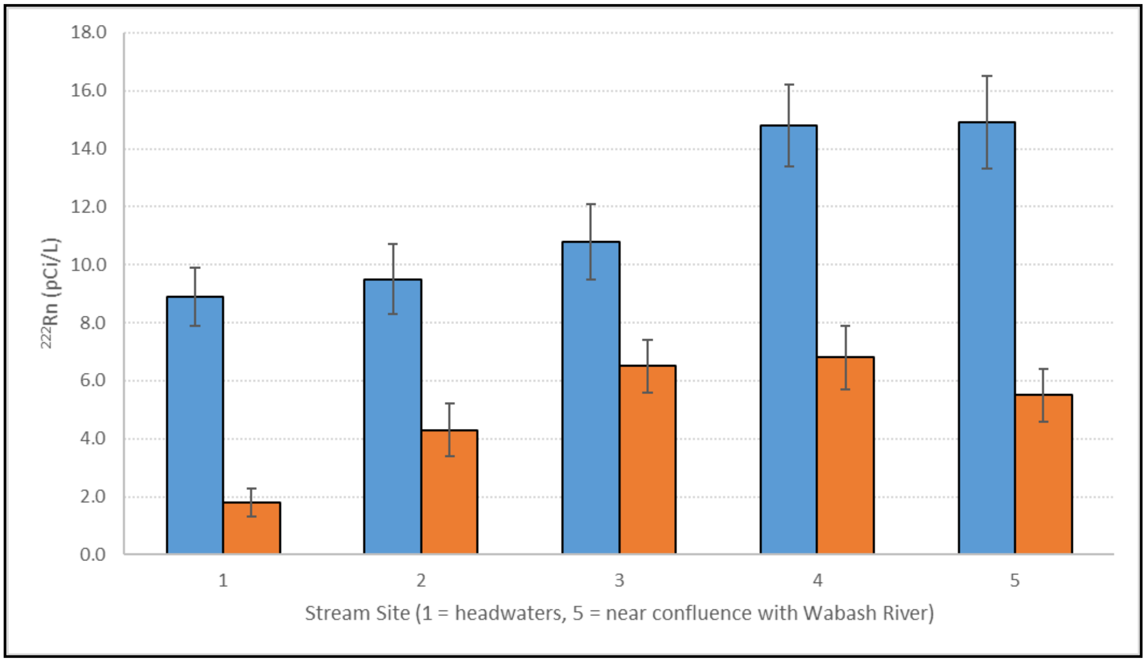

Figure 5: ^{222}Rn concentrations measured in streamflow at Ross Hills Park. Stream 1 (blue bars) drains the Ross Hills Preserve and Stream 2 (orange bars) drains agricultural land (samples shown were collected in September 2015).

The acquisition of ^{222}Rn flowing through soil and/or rock occurs due to the decay of ^{238}U in uranium-bearing rocks. Since glacial till in this region contains a high proportion of uranium-bearing plutonic clasts, the ^{222}Rn observed in the streams could possibly represent flow through the till and/or till soil. The results from the 4-week rock-leaching experiment indicate that the highest concentrations of ^{222}Rn in-growth occurred in the glacial till samples, whereas, the ^{222}Rn concentrations in sandstone and shale were remarkably similar (Figure 6). The ^{222}Rn concentration of till at the end of 4 weeks (17 pCi/L) is very similar to the ^{222}Rn concentrations measured at both Ross Hills streams and stream 2 at Shades State Park. Radon-222 was not measurable in subsurface runoff collected from intermittent seeps occurring through the gravelly intertill layers at Ross Hills. However, an average ^{222}Rn concentration of 264 +/- 48 pCi/L was measured in perennial seeps flowing from the toe of the slope along the till/sandstone contact. We infer that glacial till can be a significant source of ^{222}Rn in these catchments, but it is unlikely that shallow or preferential flow through the soil characterized by short residence-time flow in the soil will acquire sufficiently high ^{222}Rn concentrations to explain the trends in streamflow. However, the groundwater table is shallow at the Ross Hills streams and likely flows within the deeper portion of the till layer. This would decrease the possibility of rapid degassing and with longer residence times, it would tend to promote higher ^{222}Rn concentrations in flow from the till. Thus, we infer that saturated flow from the till may be a significant component of streamflow generation at Ross Hills, but the streams at Shades, especially stream 1, are likely controlled by flow through the underlying bedrock (hence the higher ^{222}Rn concentrations). The in-growth experiment was modified and re-initiated with the goal of providing larger volumes of water for additional analyses. The larger volumes of water should reduce the uncertainty error observed with smaller volumes and allow us to quantify ^{222}Rn in-growth in other rock types common throughout Indiana and quantify the effect of longer time scales.

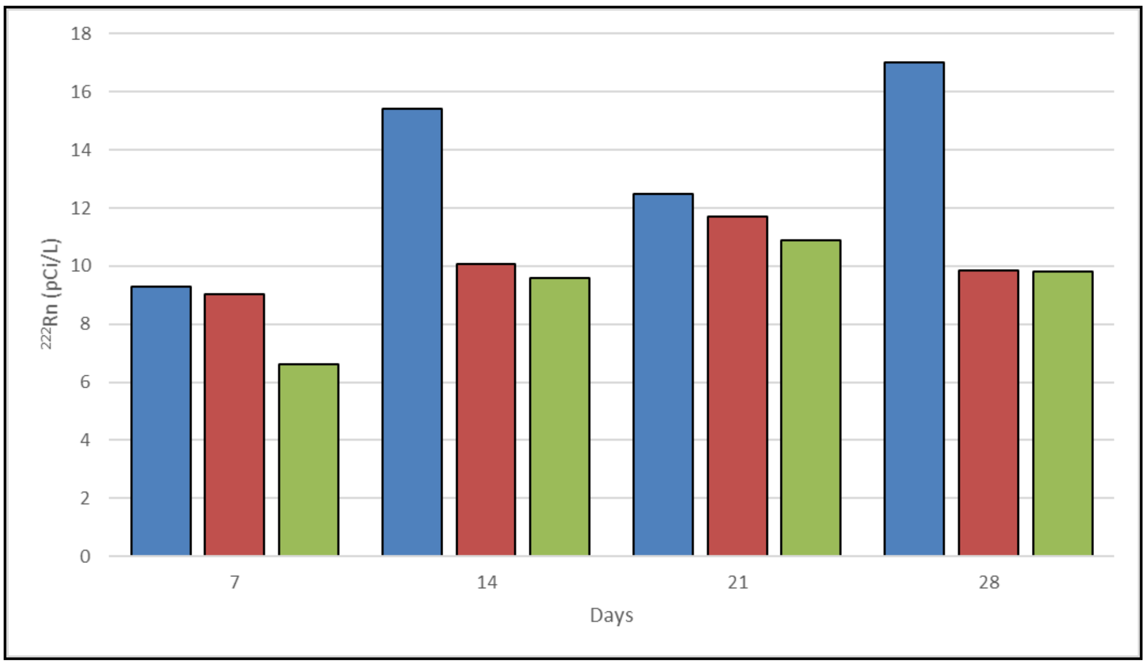

Figure 6: Results from rock leaching and ^{222}Rn in-growth laboratory experiment for glacial till (blue bars), sandstone (red bars), and shale (green bars). Analytical uncertainty was quite high due to small size of in-growth containers (500 mL).

Thermal-imaging of seeps, springs, and streams using a FLIROne camera (see: http://www.flir.com/flirone/ios-android/) indicates that perennial seeps and springs in Ross Hills are always associated with temperature anomalies (Figures 7,8) compared to streamflow. In many cases, these seeps and springs also show elevated iron-concentrations in the discharging flow and the presence of iron-precipitate near the groundwater emergence. The water at the termination of the 4-week rock leaching experiment was filtered and submitted for geochemical analyses. These analyses indicate that the glacial till is a significant source of iron, calcium, and magnesium (Figure 9). However, this simple plot cannot be used a mixing diagram because: 1) the volume of readily weathered material is much greater in the till than the other rock units and 2) the geochemical kinetics of the till are much faster than the other rock units. As a result, the solute weathering release potential is much greater in the till. Therefore, infiltrating water which flows through the till will acquire an elevated geochemical composition and if the water percolates into the underlying bedrock, the geochemical composition will change much more slowly. The end result is that flow through the till can mask subsequent geochemical evolution. We proposed to use age-dating tracers (CFCs and ^{36}Cl) and other environmental tracers (^{87}Sr/^{86}Sr) to differentiate the various flowpaths and geochemical pathways to the streams. Unfortunately, due to the late nature of sampling in 2015, these samples were submitted late and many of the analyses are still pending.

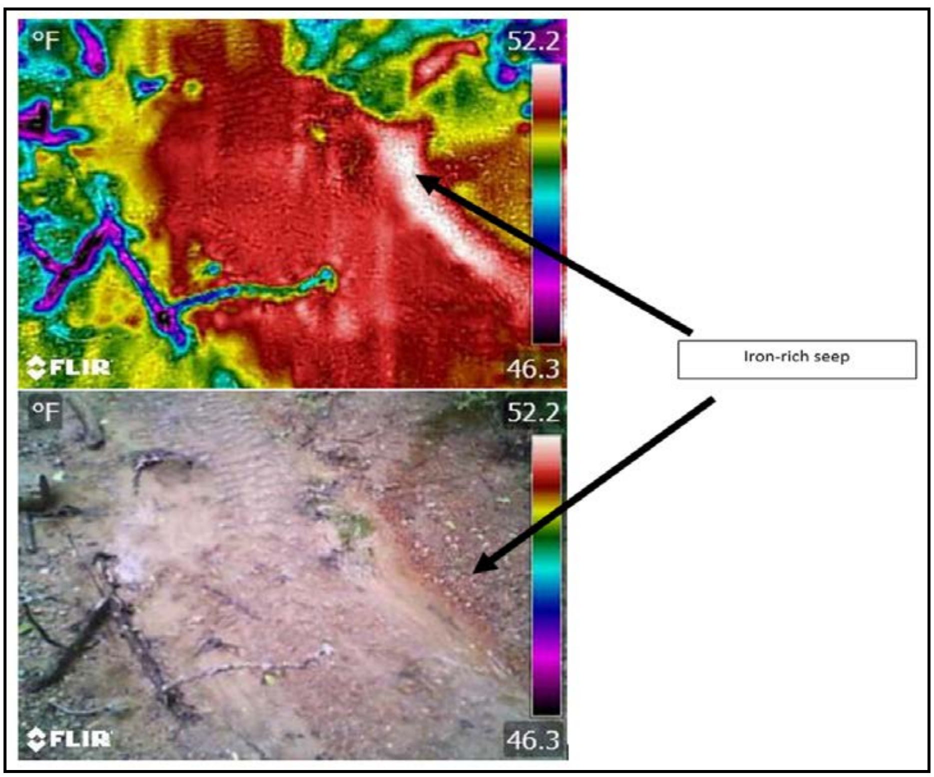

Figure 7: Thermal image taken on 2016/05/14 of an iron-rich seep emerging near a stream in Ross Hills Park.

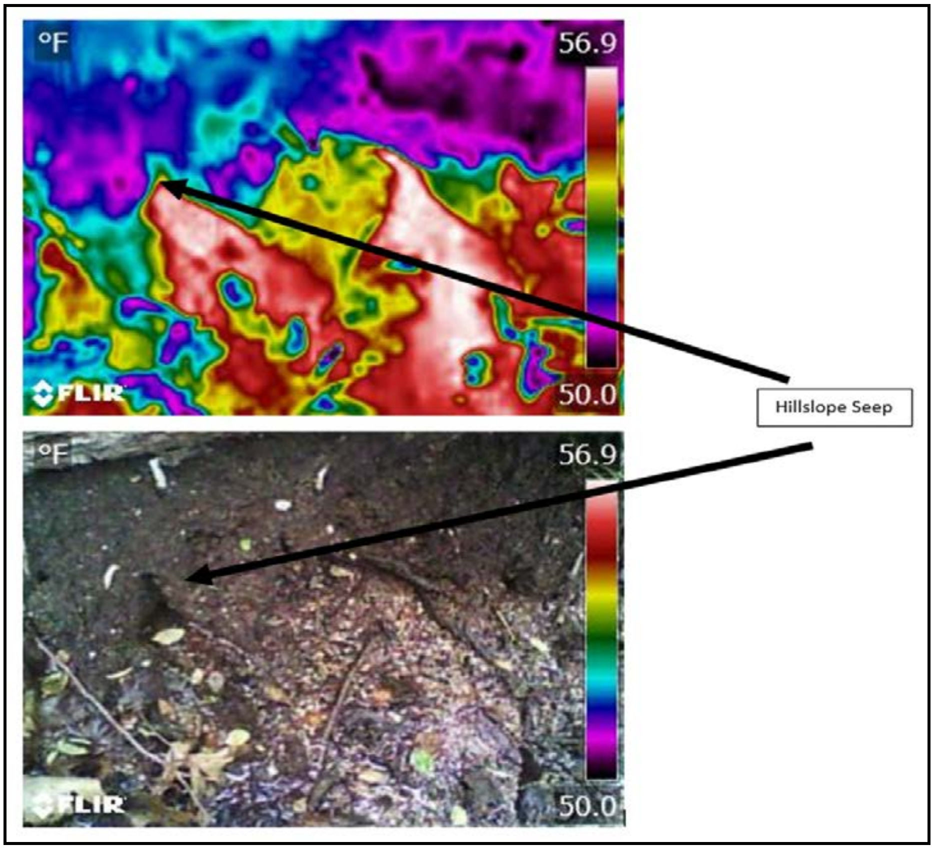

Figure 8: Thermal image taken on 2016/05/14 of perennial hillslope seeps emerging from gravelly intertill layer in Ross Hills Park.

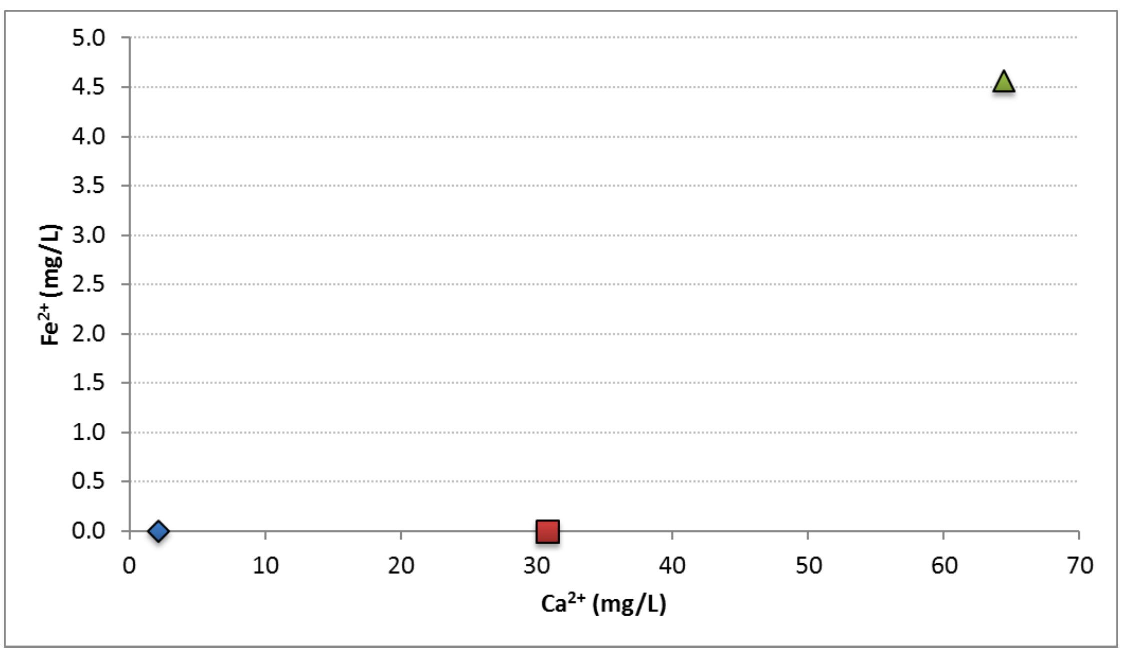

Figure 9: Results from 4-week rock leaching experiment showing differences in iron and calcium for glacial till (green triangle), sandstone (blue diamond), and shale (red square).

These data suggest that groundwater plays a significant role in streamflow generation in these small catchments draining to Sugar Creek (a large tributary of the Wabash River) and the Wabash River itself. During October and November of 2015, 29 sampling sites were established on the Wabash River and its major tributaries (Figure 10). Radon-222 was measured at each site, and samples were collected for geochemical analyses and age-dating. These analyses are still pending due to the late submission of the samples to external labs. However, the results from the ^{222}Rn analyses are encouraging and indicate that groundwater is present in “baseflow” in the Wabash River (Figure 11) and its major tributaries (Figure 12). Radon-222 concentrations are highest in the mid- and lower-reaches of the Wabash River and in the Vermilion River, Sugar Creek, and Raccoon Creek in the mid-reaches of the watershed.

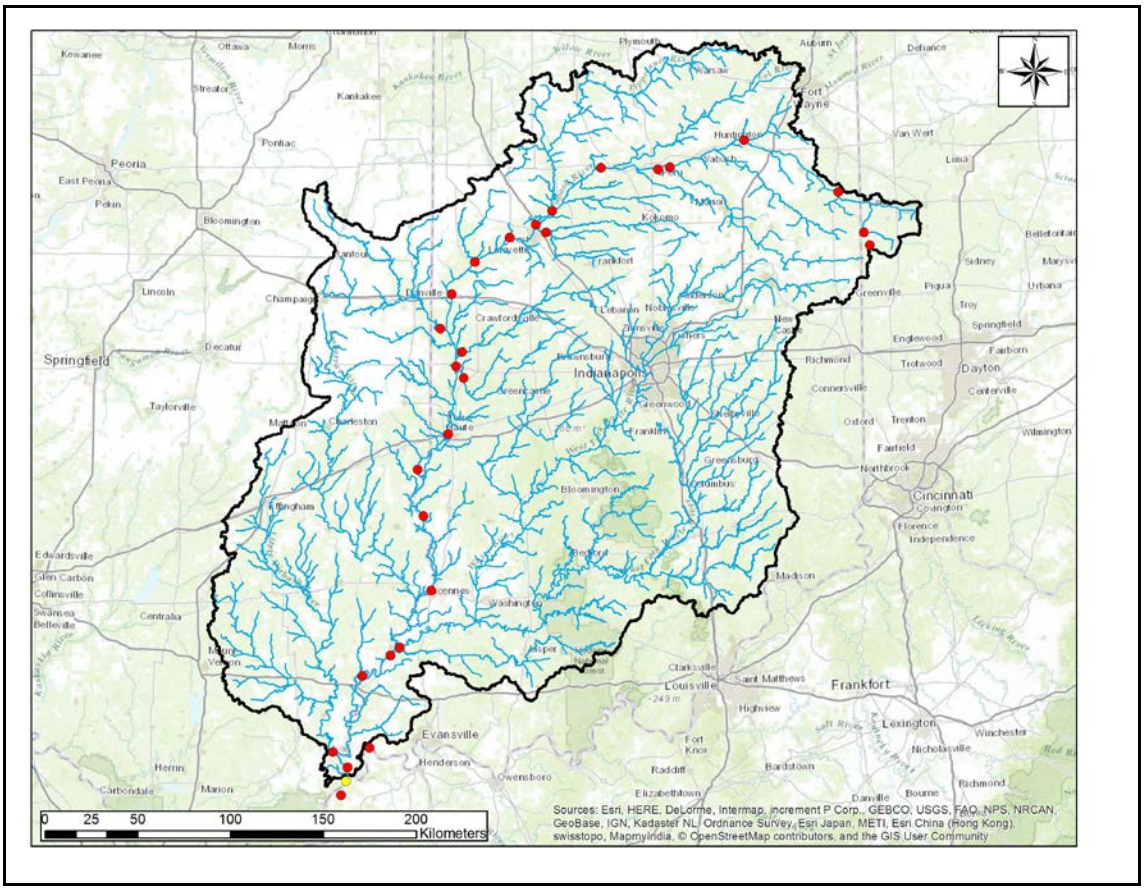

Figure 10: Map of the Wabash River watershed showing the sampling sites (red dots) located on the Wabash River, its major tributaries, and Ohio River confluence.

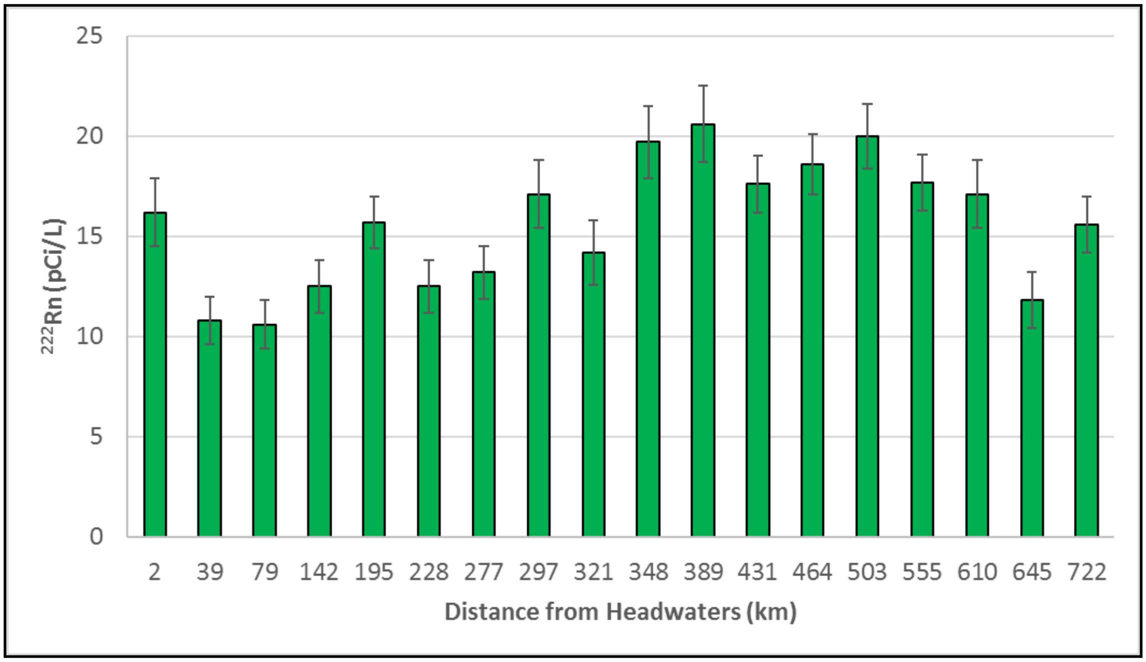

Figure 11: ^{222}Rn concentrations measured at sampling sites located along the Wabash River. Distance is measured downstream from the headwaters in Fort Recovery, OH.

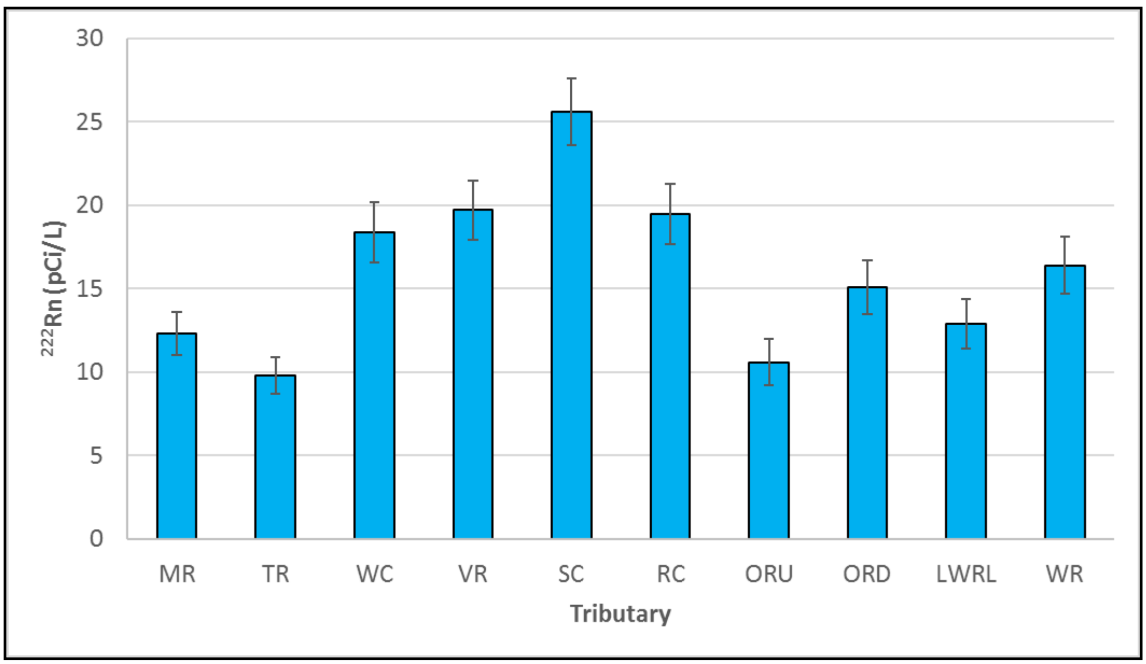

Figure 12: ^{222}Rn concentrations measured in major tributaries to the Wabash River (MR = Mississinewa River, TR = Tippecanoe River, WC = Wildcat Creek, VR = Vermilion River, SC = Sugar Creek, RC = Raccoon Creek, LWRL = Little Wabash River – lower, and WR = White River). Two samples were taken near the confluence with the Ohio River (ORU = Ohio River upstream of confluence, ORD = Ohio River downstream).

Major Conclusions and Significance:

The preliminary results are encouraging and suggest that groundwater is an important source of streamflow and baseflow generation in the smaller tributaries draining into Sugar Creek (a larger tributary of the Wabash River) and into the Wabash River itself. Groundwater was identified by the presence of elevated ^{222}Rn concentrations in streamflow that point to groundwater flow through till and flow through the underlying sandstone and shale. Since there is no atmospheric source of ^{222}Rn and surface-water in equilibrium with the atmosphere usually has little to no ^{222}Rn, these data indicate that groundwater must be discharging to these streams. It is unlikely that tile-drainage water will contain significant concentrations of ^{222}Rn since the shallow unsaturated zone is aerated. It is also unlikely that return flow from water treatment plants will contain significant concentrations of ^{222}Rn since the treatment process provides ample time for degassing. Very little is known about groundwater/surface-water interactions in large rivers such as the Wabash River and even less is known about those interactions in large, agricultural watersheds. The forthcoming environmental tracer data using age-dating and geochemical tracers will hopefully shed more light on the sources, magnitude, and residence-time of groundwater in streamflow in these agricultural watersheds.

Publications:

Madison Hughes, P. Bogeholz, and M.D. Frisbee (November 2015), Quantifying Groundwater/Surface-water Interactions in Small Tributary Drainages to the Wabash River using Radon-222 and Other Environmental Tracers, GSA Annual Meeting, Baltimore, MD, undergraduate research poster.

Frisbee, M.D., Z. Meyers, N. Stewart-Maddox, M. Hughes, and C. Wayman (2016), Identifying sources of streamflow and baseflow in 4 small catchments draining agricultural land in the Wabash River watershed, Water Resources Research, in preparation.

Grant Submissions:

Grants for continuing this research have not been submitted as of this writing. However, a larger grant is anticipated to be submitted to the NSF Hydrological Sciences division or USDA NIFA in 2016/2017.

Students:

The majority of this grant was used to pay for analytical costs. However, 3 undergraduate students and 2 graduate students were involved in the research. The undergraduate students were Philine Bogeholz (Purdue SURF 2015 student), Madison Hughes (Purdue EAPS), and Callum Wayman (Purdue Multi-Eng/Geo-Eng). They assisted in the collection of water samples, and analyzed the geochemical and isotopic data. Madison and Philine presented poster on their research at the GSA 2015 Annual Meeting in Baltimore, MD. The graduate students were: Zach Meyers (Purdue EAPS, PhD) and Noah Stewart-Maddox (Purdue EAPS, MS). They helped collect the water samples, and helped analyze and interpret the chemical and isotopic data.

Abundance and effects of pharmaceuticals on game fish in central Indiana

Basic Information

Title:	Abundance and effects of pharmaceuticals on game fish in central Indiana
Project Number:	2015IN382B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	IN-006
Research Category:	Not Applicable
Focus Category:	Agriculture, Ecology, Hydrology
Descriptors:	None
Principal Investigators:	Melody J. Bernot

Publication

1. None

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

Title: Abundance and effects of pharmaceuticals on game fish in central Indiana

Project Type: Research

Project Id: 2015IN382B

Period: March 1, 2015 – February 28, 2016

Congressional District: IN-006

Focus Categories: AG, ECL, HYDROL, NPP, ST, SW, TS, WQL

Keywords: contaminants, nonpoint pollution, streams, toxicology

Principal Investigators:

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Abstract / Summary:

The prevalence of pharmaceuticals in aquatic ecosystems is apparent; however, our understanding of the potential adverse effects of pharmaceuticals on aquatic organisms is limited. We evaluated acute and chronic toxicity of carbamazepine on yellow perch. An acute toxicity experiment was conducted over 48 h to quantify yellow perch response to carbamazepine concentrations across a range of concentrations (0 – 60 mg L^{-1}). Acute tests quantified an LC_{50} of 17.5 mg L^{-1} on yellow perch. Chronic toxicity tests were conducted over 65 d to quantify fish response to environmentally relevant concentrations of carbamazepine (0 - 12 µg L^{-1}). Fish exposure to 12 µg L^{-1} resulted in reduced growth measured as lower total body length and weight. Further, exposure altered yellow perch behavior as reduced response to stimulus. These data suggest carbamazepine has adverse effects on aquatic organisms at concentrations regularly measured in freshwater ecosystems. Further, behavioral toxicity at nonlethal concentrations should be considered as an early warning system to potential changes in population dynamics in aquatic ecosystems.

Problem:

Preliminary data indicate both human and veterinary PPCPs are ubiquitous in freshwaters throughout central Indiana. However, continued research is needed to understand how PPCPs affect, and persist in, aquatic organisms. Proposed research will combine descriptive sampling with in vitro experiments to directly quantify bioaccumulation of PPCPs in fish and their response as change in behavior and growth. Research will focus on four compounds of high priority (acetaminophen, carabamazepine, DEET, triclosan) due to their abundance in central Indiana and their potential for toxicity.

Research Objectives:

The overall objective of this study is to quantify abundance and effects of PPCPs in sentinel game fish species of central Indiana.

Methodology:

Abundance of PPCPs in game fish tissue — In the summer of 2015, population estimates of select game fish (bluegill, bass, catfish) was conducted at three sites popular among local anglers on the main stem of the Upper White River. Fish lipid content is typically highest in late summer and this timing will maximize potential pharmaceuticals in fish tissue. Sites were located in Muncie, Indianapolis, and Bloomington, Indiana. At each site, a 100 m reach of the river was isolated using seines at the uppermost and lowermost point of the reach. Following isolation, fish were sampled to depletion using electroshock techniques for calculation of population size by fish species. All game fish collected (bluegill, bass, and catfish) were counted, weighed and measured. Five fish from each size class and game species collected were returned to the laboratory for measurement of pharmaceutical concentrations in tissues. All other fish were returned to the river unharmed. Following collection of target game fish, dissection of muscle and liver tissue of each fish independently was conducted using stainless steel scissors. Each liver and muscle tissue sample was individually wrapped in aluminum foil and placed in food-grade polyethylene bags (*sensu* Ramirez et al. 2009). Samples were frozen on dry ice within 24 h of collection and brought to the analytical laboratory for analysis of pharmaceutical compounds (N = 26 compounds) in fish tissue using HPLC-MS/MS (*sensu* Ramirez et al. 2009) following grinding using a high speed blender to ensure maintenance of frozen tissue through addition of dry ice throughout. We have conducted preliminary fish tissue analyses and analyzed pharmaceuticals concentrations in natural populations of fish at ng/g concentrations.

Fish response to pharmaceutical mixtures — Laboratory mesocosm experiments testing both direct effects (toxicity) and indirect effects (changes in growth rate and behavior) were conducted to assess the influence of pharmaceutical mixtures (at environmentally-relevant concentrations) on fish. Research used frameworks established in terrestrial ecology assessments of the influence of species diversity on ecosystem function (Tilman et al. 2006; Tilman et al. 2007) to understand how pharmaceutical compound diversity influences aquatic organisms. Pharmaceutical compounds were identified by functional group (e.g., antibiotic, anticoagulant) and statistically assigned treatments to relate the diversity of pharmaceutical functional groups to organismal response. Synergistic and antagonistic effects of multiple pharmaceutical functional groups were also measured. EPA methods (EPA-821-R-02-013) were used for chronic toxicity experiments over 60 days in replicate aquaria consisting of cover (half-pipe PVC) and 10 individual fish each. PPCP concentrations were applied at mean concentrations measured in the UWR (Bunch

& Bernot 2011; Veach & Bernot 2011; Bernot et al. 2013) and compared to a control (No PPCPs). Treatment concentrations were maintained through weekly water changes and tanks were checked daily for pH, oxygen, and mortalities. Fish size (as length and girth) was measured weekly in addition to bi-weekly measurement of behavior. Behavior was measured as both habitat use and response to stimulus.

Results

Acute toxicity

Lethal concentrations 50 (LC_{50}s) were quantified in four different models (logistic 22.4 mg L^{-1}; loglogistic 21.2 mg L^{-1}; probit 21.2 mg L^{-1}; weibull 17.5 mg L^{-1}). Weibull model showed the lowest estimated LC_{50} (17.5 mg L^{-1}) and the narrowest range (5.6) of 95 % confidence intervals in LC_{50} (Table 2). Therefore, we concluded that the acute toxicity of carbamazepine on yellow perch was 17.5 mg L^{-1}. In LC_{10} and LC_{90}, Weibull model also showed lowest estimated values with narrowest ranges of confidence interval.

Chronic toxicity

For the first 10 days, fish total body length increased but total body weight decreased across all treatment concentrations. After the 10th day, fish began to eat and both total body length and total body weight increased over time.

Every treatment group had significant changes in total body length and weight after 65 days of carbamazepine exposure, except total body weight of the highest concentration (12 µg L^{-1}; t = -1.88, p = 0.07). Most treatment groups had significant changes in total body length and weight over the 65 d incubation, consistent with natural growth curves. However, fish exposed to 12 µg L^{-1} carbamazepine (highest exposure) had reduced rate of increase in total body weight relative to other treatments (t = -1.88, p = 0.07).

For total body length, there were interactions between exposure duration and carbamazepine concentrations (F = -0.007, p = 0.017), fish tanks and exposure duration (F = -0.014, p = 0.006) and fish tanks and carbamazepine concentrations (F = -0.276, p=0.0004). For total body weight, there were interactions between exposure duration and carbamazepine concentrations (F = -0.019, p = 0.0006).

Fish behaviors were observed for 35 days. There was no difference in number of fishes resting or using cover in treatment concentrations. However, the 12 µg L^{-1} treatment

concentrations yielded more active fish, but activity was only significantly different from fish exposed to 6 µg L^{-1} carbamazepine. The number of non-responsive fish was higher in the 6 µg L^{-1} and 12 µg L^{-1} treatments relative to the control and 3 µg L^{-1} treatments. Fish ingested 68.9 to 74.9 % of food provided and egested 2.8 to 4.2 % as feces. Weight increase from day 52 to day 65 ranged 12.2 to 14.9 %. Control and 3 µg L^{-1} carbamazepine exposure showed similar patterns in ingestion efficiency. Although fishes in 6 µg L^{-1} treatment group were smaller in length and weight, they gained the most weight over the study period which could explain the lower amount of excretion measured. Fish in the 12 µg L^{-1} carbamazepine treatment had the highest ingestion, but the lowest increase of body weight (9.58 g) during the period. There were no differences in ingestion efficiency variables among carbamazepine treatments (Ingestion $F = 0.137$, $p = 0.724$; Weight gained $F = 0.114$, $p = 0.747$; Egestion $F = 0.438$, $p = 0.533$).
Fish tissue analyses are still underway for measurements of PPCP concentrations.

Major Conclusions and Significance:

Carbamazepine can be considered as 'slightly toxic (> 10 – 100 mg L^{-1}) based on acute toxicity LC_{50} calculations (17.5 mg L^{-1}), consistent with previous research. Chronic exposure to environmentally relevant concentrations of carbamazepine reduces yellow perch growth rates and changes behaviors. Since the concentrations between acute (17.5 mg L^{-1}) and behavioral toxicity (12 µg L^{-1}) span three orders of magnitude, the acute toxicity cannot be used to predict the potential for adverse effects of carbamazepine in aquatic ecosystems. Therefore, we need to consider behavioral toxicity as an alternative endpoint at nonlethal concentrations as an early warning system for better prediction of adverse effects and management of aquatic ecosystems.

Publications/Presentations:

Lee, JH, MJ Bernot. 2016. The toxicity and effects of carbamazepine on Dreissena mussels and Yellow Perch. Indiana Academy of Science. Indianapolis, IN. March.

Lee, JH, MJ Bernot. 2015. The toxicity and effects of carbamazepine on aquatic invertebrates. Society for Freshwater Science. Milwaukee, WI. May.

Zello, S, MJ Bernot. 2016. Multi-stressor effects of PPCPs on Daphnia magna mortality, reproductive activity and growth. BSU Student Symposium. March.
Lee, JH, MJ Bernot. 2016. The toxicity and effects of carbamazepine on aquatic invertebrates. Ball State University Student Symposium. March.

Grant Submissions:

Bernot, MJ, RJ Bernot. NSF Environmental Engineering. Submitted October 2015. A multi-scale systems approach to evaluating ecological impacts of pharmaceuticals and personal care products (PPCPs) in freshwaters. Total Request: $304,532. In review.

Students:

2 graduate students, Ball State University: Jee Hwan Lee, Jason Doll
2 undergraduate students, Ball State University: Scott Zello, Misael Lopez

Developing a predictive model for algae-bacterial associations in the Wabash River Watershed

Basic Information

Title:	Developing a predictive model for algae-bacterial associations in the Wabash River Watershed
Project Number:	2015IN383B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	IN-006
Research Category:	Not Applicable
Focus Category:	Ecology, Management and Planning, Models
Descriptors:	None
Principal Investigators:	Kevin H Wyatt

Publication

1. None

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

Title: Developing a predictive model for algae-bacterial associations in the Wabash River Watershed

Project Type: Research

Project Id: 2015IN383B

Period: March 1, 2015 – February 28, 2016

Congressional District: IN-006

Focus Categories: ECL, M&P, MOD, WQL, WU

Keywords: algae, bacteria, *Cladophora*, dissolved organic carbon, streams, temperature, water quality

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Abstract / Summary

Nutrient contamination within the Wabash River Watershed has resulted in the growth of nuisance macroalgae, including *Cladophora glomerata*. The presence of *Cladophora* has implications for water quality and public health because it harbors fecal indicator bacteria and several species of pathogens. One mechanism that would allow *Cladophora* to support bacterial communities is through the release of energy rich dissolved organic carbon (DOC). This study assessed the effect of temperature on the release of DOC from *Cladophora* and the subsequent uptake by bacteria in order to increase our understanding of the mechanisms that control algal-bacteria associations. This research was guided by three objectives: 1) conduct a survey within the Wabash River Watershed to establish relationships between temperature, *Cladophora* productivity, and DOC release, 2) perform controlled laboratory experiments to examine temperature controls on DOC release by *Cladophora* and its use by bacteria, and 3) develop a predictive model for *Cladophora*-associated bacteria within the Wabash River Watershed. Biomass-specific primary production and DOC release were measured from *Cladophora* during the winter, spring, and summer throughout eutrophic streams of Indiana. Field measurements were coupled with laboratory incubation experiments to evaluate the influence of temperature on the uptake of algal DOC by heterotrophic bacteria. In the field, *Cladophora* showed seasonal differences in GPP and DOC release. Algal production increased from 2 mg C L^{-1} g^{-1} h^{-1} in winter to 14 and 16 mg C L^{-1} g^{-1} h^{-1} in spring and summer, but DOC release was greatest in spring, when water temperature was at the physiological optimum for *Cladophora* (15°C). Laboratory incubation experiments indicated that temperature had a significant effect on the release of DOC by *Cladophora* and DOC release was correlated with productivity. Bacterial growth (10^6 cells mL^{-1}) increased rapidly in the presence of algal DOC, but the increase was greater during the spring when temperature conditions were optimal for *Cladophora* growth (15°C) compared to winter (5°C) and summer (25°C) water temperature. Algal-derived DOC was subsequently degraded by bacteria, and degradation was greatest at 15°C when bacterial density was at its maximum. The results of this study demonste that bacteria rapidly use algal DOC and that primary production of *Cladophora* and associated uptake of DOC by heterotrophic bacteria was influenced by temperature. Consequently, we can use temperature thresholds to predict the occurrence of heterotrophic bacteria related to elevated levels of labile exudates provided by *Cladophora* growing in physiologically favorable conditions (ca. 15°C). These findings can also be used to predict how changes in the water temperature will influence such associations within the Wabash River Watershed.

Problem:

Nutrient enrichment within the Wabash River Watershed has resulted in environmental degradation including the occurrence of *Escherichia coli* and pathogenic bacteria associated with the macroalga *Cladophora glomerata* (IDEM 2006). *E. coli* is generally associated with fecal waste (sewage) and their densities have been used to predict the presence of microbial pathogens that also come from fecal waste. Because *E. coli* can occur in the presence of *Cladophora* but in the absence of fecal waste, it is possible that the public health risk is overstated where *Cladophora* is present (Byappanahalli et al. 2003, Englebert et al. 2008). Conversely, *Cladophora* may present an increased risk to human health in the absence of fecal contamination if it harbors bacterial pathogens. Previous studies on the occurrence of fecal and pathogenic bacteria in *Cladophora* have ignored the overall condition of the alga. For example, it is unclear if fecal and pathogenic bacteria only occur in anaerobic conditions in dead and decaying mats of *Cladophora* or if they form part of the bacterial communities of healthy and actively growing algal populations. Such information is critical for managers because it determines if public health risks are associated with blooms of living *Cladophora* (attached to the stream bottom) or only when the alga washes onto the shore.

One mechanism that would allow actively growing *Cladophora* to support bacterial communities is through the release of energy rich dissolved organic carbon (DOC). Previous studies have shown that *Cladophora* can release up to 90% of its daily fixed carbon as DOC (Wyatt *et al.* 2014a). The release of DOC is thought to operate as an overflow mechanism under circumstances where light levels support rates of photosynthesis that exceed the capacity of the algae to use carbohydrates in growth (Smith and Underwood 2000). The release of DOC can, in turn, stimulate bacteria which use this labile organic matter for metabolism (Giroldo *et al.* 2007, Wyatt *et al.* 2012).

The amount and composition of DOC released by algae varies with environmental conditions (Wyatt *et al.* 2014b). Environmental factors, such as temperature, will likely have the strongest influence on the release of DOC because it has the greatest effect on photosynthesis (Davison 1991). Temperature also has an important role in heterotrophic metabolism (Wetzel and Likens 2000). In addition to seasonal changes in temperature, recent assessment of the Wabash River Watershed indicates that climate change will result in a longer growing season with higher temperatures (USACE 2011). Examining the role of temperature in controlling the release of algal DOC and how it is used by bacterial communities will help to determine the mechanisms structuring *Cladophora*-bacterial associations. This mechanism can be used to predict how changes in the water temperature will influence such associations within the Wabash River Watershed.

Research Objectives:

The goal of this research was to increase our understanding of the mechanisms that control the interaction between *Cladophora* and bacteria. The objectives were to:

1. Conduct a survey within the Wabash River Watershed to establish relationships between temperature, *Cladophora*, and the release of dissolved organic carbon (DOC).
2. Perform controlled experiments to examine temperature controls on DOC release by *Cladophora* and its use by bacteria.
3. Link the field surveys and experimental work to develop a predictive model for *Cladophora*-associated bacteria within the Wabash River Watershed.

Methodology:

Survey: Stream sites throughout the Wabash River Watershed were selected for measurements of *Cladophora* biomass-specific gross primary productivity (GPP) and DOC release. Sites were sampled during the winter, spring, and summer. On each sampling campaign, GPP and DOC release were evaluated *in situ* using biological oxygen demand (BOD) bottles. Twelve clear 300 mL BOD bottles were filled with 0.2 µm (VacuCap filter, Pall Life Sciences, Ann Arbor, Michigan) filtered river water and placed in the river to reach ambient temperature. Approximately 1 g of *Cladophora* was added to each bottle and incubated in the river for 1 h under ambient light to measure O_2 production (net primary production [NPP]). Dissolved oxygen was measured before and after each incubation with a luminescent DO probe (Hach Hydromet). The bottles were then wrapped in aluminum foil and left for an additional hour to measure O_2 consumption (dark respiration [R_d]). Water samples were collected before and after each light incubation using a syringe fitted with a rubber tube and filtered through a 0.45 µm syringe filter for evaluation of DOC release (Wyatt et al. 2014). Following the dark incubations, the algal material was dried at 60˚ C for 24 h to measure dry mass. Gross primary production was calculated from NPP and R_d and converted into units of C following Wetzel and Likens (2000) using a C:O molar ration of 0.375 and a photosynthetic quotient of 1.2. Dissolved organic carbon release was calculated as the difference in DOC concentration before and after each light bottle incubation. Productivity and DOC release are expressed as biomass specific carbon generation (mg C L^{-1} g^{-1} h^{-1}). Chemical and physical data were collected concurrently with biological samples. Dissolved nutrients were analyzed following standard methods (APHA 1998). Temperature, dissolved oxygen, turbidity, pH, and conductivity were measured using Hydrolab multi-probes. Physical habitat variables such as water depth and substrate composition were assessed at each sampling site.

Temperature controls on DOC release and bacterial uptake: A laboratory experiment was used to evaluate the importance of temperature on the release of DOC from *Cladophora* and the subsequent uptake of DOC by heterotrophic bacteria. *Cladophora* was grown in 0.2 µm-filtered water in the lab for 36 hours. After 36 hours, algal material was removed and the concentrated DOC solution was filtered into 16-300ml flasks diluted to equal DOC concentration (ca. 20 mg L^{-1}). Each flask was randomly assigned to one of four experimental treatments (5, 15, and 25°C), with four replicates each. Flasks were kept in the dark and temperature was kept constant by circulating water around each flask using separate circulating water baths. A natural bacterial inoculum was prepared by filtering water from the White River through a 0.7 µm filter. One mL of the bacterial inoculum was pipetted into each flask. Flasks were sampled at 0, ½ 1, 2, 3, 8, 16, and 32 days for measures of DOC concentration and bacteria growth. Bacteria density was quantified by direct counts using an epifluorescence microscope with UV and a light source after staining the cells with 4', 6-diamino-2-phenylindole (Porter and Feig 1980).

Development of predictive model: Chemical/physical and land use/cover data were analyzed using principal components analysis (PCA). Correspondence analysis (CA), detrended correspondence analysis (DCA), and non-metric multidimensional scaling (NMDS) were used to analyze biotic data and develop a predictive model to predict hotspots of algal-bacterial activity. A one-way analysis of variance (ANOVA) followed by a Tukey's Honestly Significant Difference test was used to analyze differences in GPP, DOC release, NO_3, PO_4, conductivity, and pH among seasons. Multiple linear regression analysis was used to identify physicochemical variables that contributed to GPP and DOC release during the survey. A univariate repeated measures ANOVA was used to evaluate differences in GPP and DOC release and bacterial cell density during laboratory incubation experiments. Linear regression analysis was used to evaluate the relationship between algal GPP and DOC release during laboratory incubations.

Results

In situ measures of GPP increased from 2 mg C L^{-1} g^{-1} h^{-1} in winter to 15 mg C L^{-1} g^{-1} h^{-1} in summer (Figure 1). Estimates of DOC release from *Cladophora* during field productivity measurements showed that the rate of DOC release peaked at 13 mg C L^{-1} g^{-1} h^{-1} in spring when average temperature was near 15˚C, the physiologically optimal temperature for *Cladophora* (Figure 2). Dissolved organic carbon release declined at water temperatures above 20 ˚C, suggesting that exudates were used for cellular growth during peak GPP instead of being released (Figure 2). Low concentrations of DOC release were measured during winter (Figure 2). Laboratory incubations showed that *Cladophora* GPP was greatest at 15˚C irrespective of the season in which it was collected (Figure 3), but was consistently elevated among experimental temperature treatments when *Cladophora* was collected during spring sampling. Similar to field measures, DOC release was elevated with warming and remained consistently low during winter incubations (Figure 4). Dissolved organic carbon release increased with GPP during spring (r^2 = 0.26, p = 0.01) and summer (r^2 = 0.17, p = 0.05) laboratory incubations, but decreased with increasing GPP during the winter incubation (r^2 = 0.23, p = 0.02; Figure 5). Bacteria growth increased in response to algal exudates, and was most elevated at 1515˚C, the physiologically optimal temperature for *Cladophora* (Figure 6). Bacterial degradation of DOC increased with greater bacterial density and was reduced at low temperatures compared with higher temperatures (Figures 7).

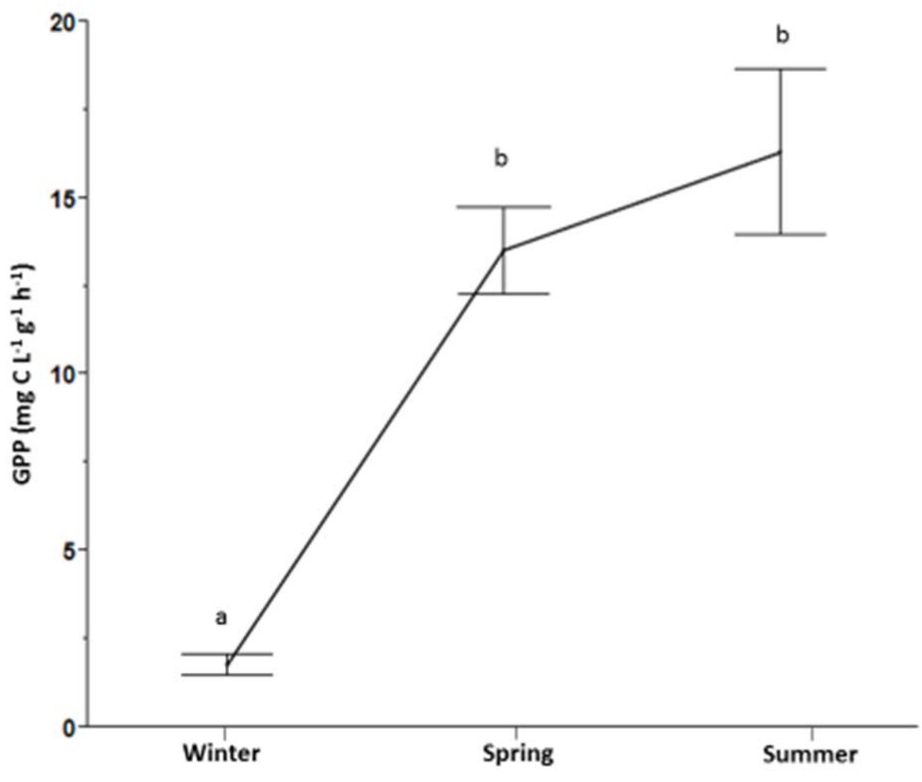

Figure 1. Mean (± 1 SE) gross primary production (GPP) of *Cladophora* in winter, spring, and summer. Significant difference indicated by different letters above bars.

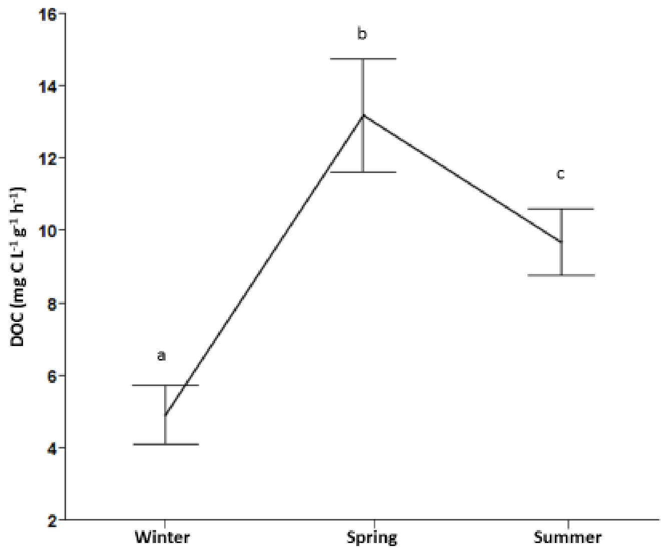

Figure 2. Mean (± 1 SE) dissolved organic carbon (DOC) release by *Cladophora* in winter, spring, and summer. Significant difference indicated by different letters above bars.

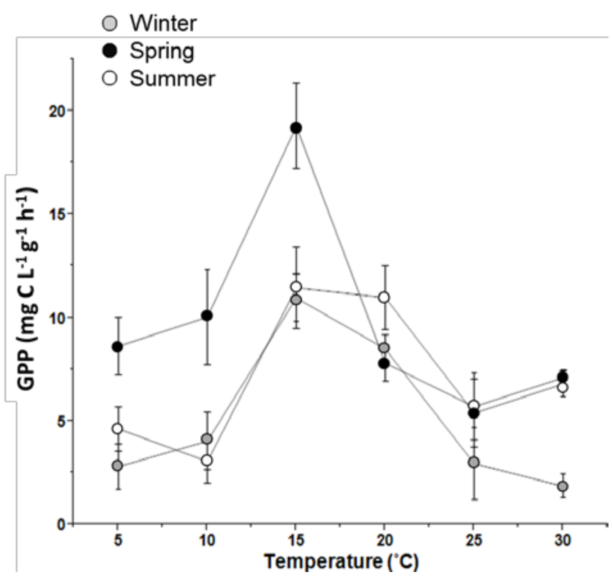

Figure 3. Gross primary production (GPP) of *Cladophora* during laboratory incubation experiments. Points represent mean ± 1 SE among temperature treatments and season.

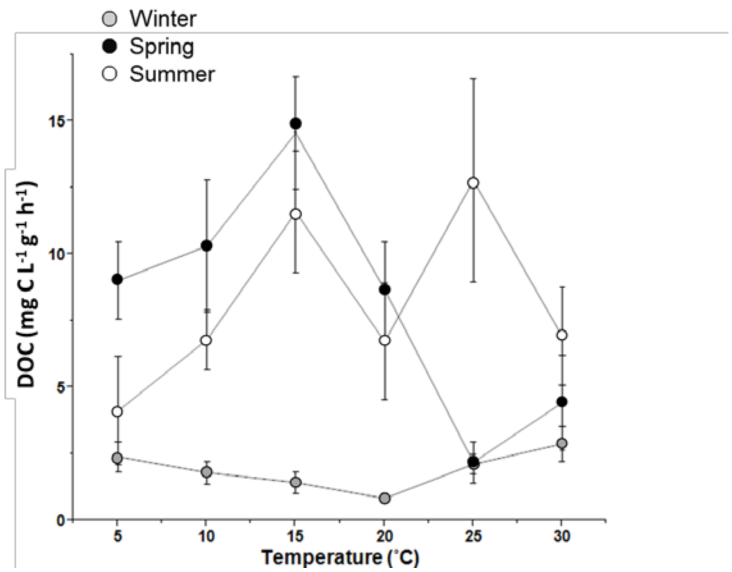

Figure 4. Dissolved organic carbon (DOC) release by *Cladophora* at experimental temperatures. Points represent mean ± 1 SE among temperature treatments and season.

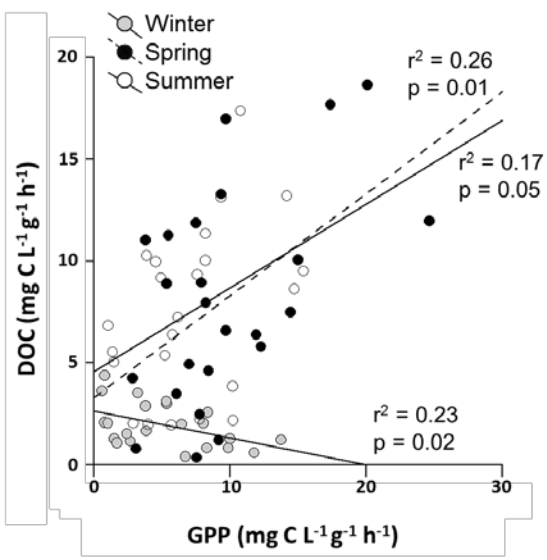

Figure 5. Relationships between algal GPP and DOC release during laboratory incubations. Lines represent regressions among experimental temperatures (winter and summer = solid, spring = dashed).

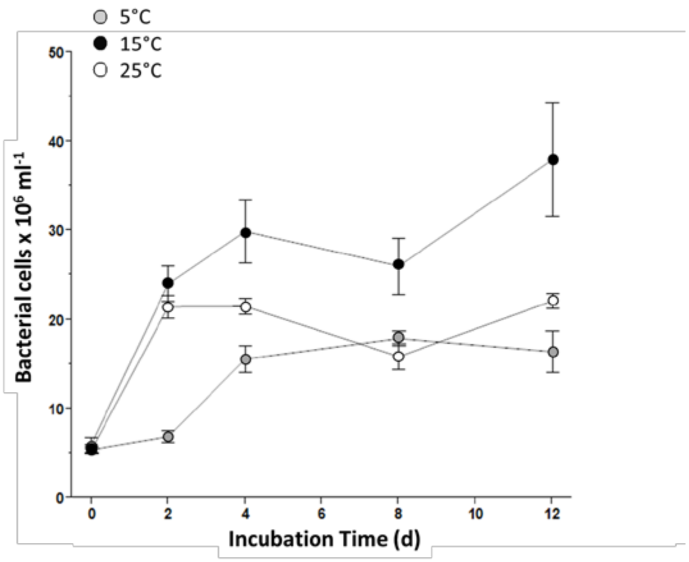

Figure 6. Bacterial cell density in a solution of algal DOC among temperature treatments during the laboratory incubation experiment. Points represent mean ± 1 SE among treatments.

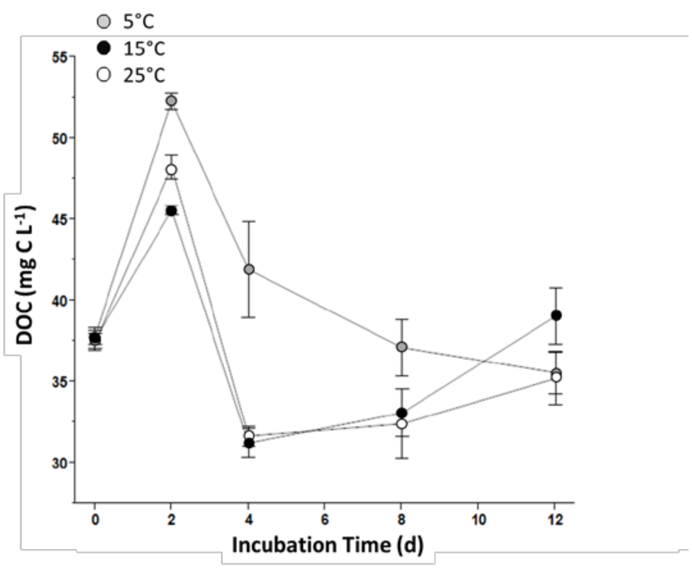

Figure 7. Bacterial degradation of algal DOC among temperature treatments during the laboratory incubation experiment. Points represent mean ± 1 SE among treatments.

Major Conclusions and Significance

The results of this study demonstrate that the release of DOC by *Cladophora* was regulated by temperature. This finding is significant given that the relationship between *Cladophora* and the abundance of heterotrophic bacteria was shown to be due to the release of DOC. Combining field and laboratory incubation observations has revealed a temperature threshold at 15˚C that regulates algal productivity, DOC release, and subsequently supports the greatest densities of bacteria. Patterns of GPP, DOC, and bacteria abundance were weakened when temperature exceeded 20˚C or was below 5˚C. Within a predictive context, these results suggest that an increase in surface-water temperatures expected with ongoing climate change will result in increased *Cladophora* production along with an increase in the availability of DOC, with possible implications for stream ecosystem processes associated with heterotrophic metabolism. This information will allow water quality managers to predict bacterial "hot-spots" and the temperatures that support the greatest growth of *Cladophora* and associated bacterial communities within the Wabash River Watershed.

Publications

**Stillwagon M, IR Davison, and KH Wyatt. 2015. Effects of temperature on the release of dissolved organic carbon from the benthic macroalga *Cladophora glomerata* in an Indiana stream. Annual meeting of the Society for Freshwater Science, Milwaukee, WI.

**Stillwagon M, IR Davison, and KH Wyatt. *In preparation*. The effects of temperature on the release and heterotrophic use of carbon exudates from benthic macroalgae in eutrophic streams.

Grant Submissions:

Support from the IWRRC allowed me, a junior faculty member at Ball State University, to initiate a research program in the Wabash River Watershed, and therefore has not yet resulted in additional grant submissions. However, forthcoming data analysis and synthesis of findings will be used to leverage funds for ongoing research.

Students

The proposed research contributed to the training and development of one MS students (Matt Stillwagon) and three undergraduate students (Jill Bange, Avery Sampson, Amanda Schurzinske) at Ball State University. Students participating in this project gained a broader understanding of the connections between chemistry, biology, and ecology as well as the opportunity to communicate their knowledge to peers, stakeholders, and the broader scientific community.

Transport and Transformation of Nitrogen, Phosphorus, and Carbon in Intermittent Streams

Basic Information

Title:	Transport and Transformation of Nitrogen, Phosphorus, and Carbon in Intermittent Streams
Project Number:	2015IN384B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	IN-009
Research Category:	Not Applicable
Focus Category:	Water Quality, Hydrology, Nutrients
Descriptors:	None
Principal Investigators:	Adam S Ward, Todd V Royer

Publication

1. Schmadel, N.M., A.S. Ward, C.S. Lowry, and J.M. Malzone (2016), Hyporheic exchange controlled by dynamic hydrologic boundary conditions, Geophys.Res.Lett., 43, 4408-4417, doi: 10.1002/2016GL068286.

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

Title: Transport and Transformation of Nitrogen, Phosphorus, and Carbon in Intermittent Stream

Project Type: Research

Project Id: 2015IN384B

Period: March 1, 2015 – February 28, 2016

Congressional District: IN-9

Focus Categories: Water Quality (WQL), Hydrology (HYDROL), Nutrients (NU), Solute Transport (ST)

Keywords: Nutrient management, water quality, riparian hydrology, nitrogen, carbon

Principal Investigators: Adam S. Ward, Todd V. Royer

Adam S. Ward (PI)

Assistant Professor

School of Public and Environmental Affairs

Indiana University

adamward@indiana.edu

812-856-4820

Abstract / Summary:

Nitrogen fertilization is a cornerstone of modern agriculture, but the practice also has led to eutrophication, hypoxia, harmful algal blooms and water quality degradation in both inland and coastal waters. Human impacts, additionally, alter loads of nitrogen and other nutrients (phosphorus, carbon) to surface waters. Nutrient export from and transformation within catchments is coupled to hydrological dynamics. The primary controls on nutrient (nitrogen, phosphorus, carbon) cycling remain poorly understood during variable flow conditions (e.g., storm events, droughts). Catchments are increasingly dynamic due to human activity (e.g., tile draining, channelization, impervious surface development), and climate change will amplify these dynamics. To predict water quality responses to changes in water quantity, an understanding of nutrient dynamics during variable hydrological conditions is required. Without a mechanistic understanding the coupled water quantity and quality dynamics of Indiana streams, the state's water resources cannot be managed in the face of future uncertainty, nor strategically leveraged as a resource to bolster economic development.

Problem:

Indiana has reached a critical juncture in terms of water-resource management due to climate-, population-, and economy-related stresses, according to a report released by the Indiana Chamber of Commerce in August, 2014. These sentiments are echoed by the Central Indiana Council of Elected Officials, who are advocating for more decision-support tools related to regional water-supply planning. Indeed, the Indiana Chamber of Commerce and others with experience in economic development have identified the state's water resources as a strategically valuable asset for attracting businesses and individuals to Indiana[Error! Bookmark not defined.].

Responding to all of these pressures and opportunities will require planning, which should be grounded in and informed by strong science. Understanding the magnitude of nitrogen (N) loss and the mechanisms responsible for attenuation within river networks is a critical research need for developing successful strategies for managing landscapes and predicting downstream nutrient flux. Surplus nutrients adversely affects many ecosystems and are equivalent to climate change and habitat loss as a leading threat to global biodiversity. Consequently, elevated nitrogen loads stress aquatic ecosystems and lead to the degradation of surface and ground water quality which are both rapidly growing global problems. Management of water quality in Indiana is critical to a sustainable water-future for the state. To manage landscapes under current conditions, predict behavior under future conditions, and implement resilient restoration projects, a process-based understanding of the linkages between hydrological forcing and biogeochemical processes is required.

Research Objectives:

To quantify the responses of stream transport and transformation processes during dynamic hydrological forcing, we will conduct field experiments on intermittent streams in southern Indiana. Our central objective is to quantify the competing processes of nutrient transport and transformation during dynamic hydrological forcing in intermittent streams.

Methodology:
We conducted a series of solute tracer studies in an intermittent stream in Indiana, collecting water quality and transport information under a range of hydrological conditions. Field samples were analyzed for major anions, major cations, and nutrients.

Results
A key finding of this study is that measures of stream and hyporheic transport were not explained by stream discharge, nor by the rate of change of stream discharge (i.e., rate of rising or falling discharge in response to storms). These findings suggest that changes in transport pathways and residence times detected by solute tracers are not the primary control on observed changes of in-stream water quality. We expect that longer timescale flowpaths, where solute tracers are not well-suited for characterization, do change during storm events. Additionally, we hypothesize that rainfall-runoff-baseflow dynamics in the catchment (broadly "hydrological connectivity") is the dominant control on in-stream water chemistry.

Major Conclusions and Significance:
Preliminary research findings suggest in-stream nutrient spiraling studied under baseflow conditions may not be representative of dynamics during high flow periods. These high-flow conditions are critical, as they represent the periods of peak nutrient export from agricultural watersheds. Additionally, our findings suggest dynamics in loading may overwhelm dynamics in in-stream processing during storm event responses in headwater streams.

Publications:
Peer Reviewed Publications:
Schmadel, N. M., A. S. Ward, C. S. Lowry, and J. M. Malzone *(*2016*)*, Hyporheic exchange controlled by dynamic hydrologic boundary conditions, Geophys. Res. Lett., 43, 4408–4417*, doi:*10.1002/2016GL068286.

Presentations:
1. Hixson, J, AS Ward, N Schmadel. Multi-scale Observation of Time-Variable Interactions of a Stream and its Valley Bottom During a Storm Event. American Geophysical Union Fall Meeting. 2015. Abstract H33C-1601.
2. Cain, M. R., A.S. Ward, N.M. Schmadel, J. Hixson. Multi-Scale observation of time-variable surface and subsurface interactions of an intermittent urban stream. European Geosciences Union General Assembly 2016. Abstract EGU2016-6915.

Grant Submissions:
1. *CAREER: An integrated research and education plan to assess stream-hyporheic-riparian dynamics from the flowpath to network scales* (2015)
   Principal Investigator(s): Adam s. Ward
   Funding Source(s): NSF Hydrologic Sciences

Total Request: $604,991
Status: Not selected for funding

2. *INFEWS/T1: How does non-stationarity expose FEW system tipping points in the agricultural Midwest? (2016)*
   Principal Investigator(s): Kristie Franz, William Gutowski, Chris Rehmann, Leigh Tesfatsion, Andrew VanLooke
   Funding Source(s): NSF INFEWS
   Total Request: $696,877 ($33,845 to Ward as Senior Personnel)
   Status: In Review

Students:
Graduate Students: 2
Undergraduate Students: 2
High-school Students: 2

Current Reduction Status Regional Tracker (CrsTracker)

Basic Information

Title:	Current Reduction Status Regional Tracker (CrsTracker)
Project Number:	2015IN401S
USGS Grant Number:	
Sponsoring Agency:	U.S. Army Corps of Engineers
Start Date:	6/1/2015
End Date:	5/31/2016
Funding Source:	104S
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Bernard Engel

Publication

1. None

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

USGS Special Projects

Title: Current Reduction Status Regional Tracker (CrsTracker)
Project Type: Research

Period: March 1, 2015 – February 28, 2016

Congressional District: (Great Lakes Watershed in parts of MN, WI, MI, IL, IN, OH)

Focus Categories: Water Quality and Nutrients

Keywords: STEPL, BMP, Phosphorous, Nitrogen

Principal Investigators:

Bernie Engel, Head and Professor;

Yaoze Liu, Postdoctoral Research Scientist;

Larry Theller, Geographic Systems Analyst;

Purdue University Department of Agricultural and Biological Engineering

Abstract / Summary

The objective of this project is to create a web-based tool, CrsTracker, that will allow users to evaluate the impacts of various best management practices (BMPs) which are installed, or proposed for installation, in multi-scale watersheds across the Great Lakes region. The goal of the impact analysis is to gain an understanding of the cumulative effects of many varied BMPs in the region. The CrsTracker ranking tool would tally total BMP acres and estimate impact (cumulative load reduction) of specific classes of BMPs in reducing nitrogen, phosphorous, and sediment. The dimension of time is added, so that BMPs whose effectiveness drops off with time are ranked differently than those that retain effectiveness long-term and do not quickly change or lose their effectiveness. The CrsTracker tool will track the current status of nutrient reduction projects with an automatically updated database, which uses a REST service to feed data into the STEPL model (Spreadsheet Tool for Estimating Pollutant Loads) engine, providing a "current standings" output which users can either quickly view or use as prepopulated parameters for detailed scenario modeling.

Problem:

There is a lack of an overall mechanism to estimate the pollution reduction produced by the many varied BMPs which have been installed or that are considered for installation by various NGO and governmental units around the Great Lakes since GLRI began. The Corps of Engineers could greatly benefit from a single catalog where various BMPs, either proposed or constructed, can be entered and tracked. The lack of data for representing BMP effectiveness changing over time makes the development of modeling technology more difficult in the project.

Research Objectives:

The ultimate goal of this tool is to keep information in a database to allow the presentation of an automatically updated "reduction status current standing" for each watershed, without requiring a dedicated analysis run by a specific user. The design would support tracking BMPs installed by particular groups to allow "crowd-sourcing" or addition of BMPs by the various groups and agencies responsible for them. The tool is envisioned as a growing, live collection of practices building out over the Great Lakes Region.

To facilitate the process, several new BMPs will be added to STEPL engine, which produces the pollution reduction estimates. Understanding the pollution reduction value of these new practices requires significant research as part of this proposal.

The project team is working with Corps of Engineers personnel to expand the list of BMPs included in the STEPL tool. The BMPs to be added include:

1) the conversion of farmland to habitat with some wetlands
2) the restoration of degraded wetlands

3) enhancement of degraded wetlands
4) restoration of riparian habitat

For the new BMPs, pollutant reduction coefficients will be developed for each practice based on scientific literature and expert opinion.

The performance of BMPs over time will also be incorporated to better simulate BMPs. The investigators have significant experience in exploring the long-term performance of a group of best management practices. Based on these experiences and scientific literature, the performance of practices over time will be described mathematically and incorporated into the BMP database and tool.

Methodology:

The research team proposes to use and adapt core technologies which are implemented in a current Purdue online model: Purdue STEPL Web (https://engineering.purdue.edu/~ldc/STEPL/). The proposed new CrsTracker tool will use the analysis module from STEPL to summarize the impacts of the proposed or installed BMPs. Data will flow between the tracking database and the software engine using state-of-the-art REST services. This design, repurposing current software systems, should allow a rapid prototyping and development sequence for the proposed tool. The design will include a public facing map-based interface. Stakeholders will be able to monitor the current state of impacts by clicking on the map. To upload BMP implementation data, stakeholders will be able to click on the map or open a spreadsheet and indicate a new BMP.

The Purdue STEPL Web model is a web-enabled version of the STEPL spreadsheet tool. The original spreadsheet was created by EPA as a set of Excel macros and enhanced several times. This version has several adaptations by Purdue researchers, such as connection to an online database of precipitation, and enhancements to optimize selection of BMPs to attain water quality goals. STEPL uses a simple approach to calculate nutrient and sediment loads from different land uses. It calculates annual load reductions resulting from various BMPs. The algorithm uses precipitation, landuse, and soil data to compute surface runoff volume, nutrient loads, and sediment delivery. The nutrients include nitrogen and phosphorous. Sources considered include cropland, pastureland, farm animals, feedlots, urban runoff, and septic systems. This project will create a software engine from the model's core and format the database to feed parameters into the engine, triggering this whenever the database is updated.

Management practices influence the computation through application of nutrient reduction efficiencies per BMP per applicable area for the list of supported practices. The list of current BMPs will be extended to include additional practices of interest to the Corps of Engineers as described above.

Results: Project Research Still in progress

Major Conclusions and Significance: Project Research Still in progress

Publications: Project Research Still in progress

Grant Submissions: none yet

Students: postdoctoral associate Yaoze Liu

Information Transfer Program Introduction

None.

Pollution Prevention Strategies for the Public

Basic Information

Title:	Pollution Prevention Strategies for the Public
Project Number:	2014IN373B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	04
Research Category:	Water Quality
Focus Category:	Ecology, Education, Groundwater
Descriptors:	None
Principal Investigators:	Fred Whitford, Jagadeesh Anmala

Publication

1. None

A. Titles: Understanding Pesticide Principles and Practical Uses—What Gardeners Should Know About Pesticides

B. Focus Categories: ECL, EDU, GW, NPP, SW, WQL

C. Key Words: Integrated Pest Management, Consumer, Water, Pesticides

D. Project Duration: March 1, 2014 to February 28, 2015. A no-cost extension was granted for February 28, 2016. Project completed.

E. Funding Requested: $6,000

F. Principal Investigator: Fred Whitford, Ph.D., Director, Purdue Pesticide Programs and Clinical Engagement Professor, Purdue University, 915 West State Street, West Lafayette, IN 47907-2054; Phone: 765-494-1284; Fax: 765-494-1556; Email: fwhitford@purdue.edu

Problem: Studies show that consumers contribute their share of pesticides into streams and rivers flowing near towns and cities. Unlike farmers and commercial application industries, reaching the public on how to reduce or prevent water contamination from pesticide use has proven challenging.

Outreach/Extension Objectives: Many land-grant universities have active Master Gardener programs that reaches a subset of the American population. To qualify as a master gardener in Indiana, the intern attends a series of weekly workshops over a 12-week period to learn about current gardening techniques. One of the required weekly workshops is called *Pesticide Safety and Pesticide Alternatives*. After passing a final examination, they are asked to volunteer 35 hours to their communities. The training, test, and volunteer hours are all part of the initial requirement to becoming a Master Gardener,

Master Gardeners go on to join a county Master Gardener association and community clubs to continue volunteering their time in helping with community projects and educational programs that teach others how to select, grow, and maintain plants in the landscape and garden. In some counties, the master gardeners answer phone calls related to consumer horticulture under the supervision of the County Extension Educator.

In this fashion, the master gardener can provide pesticide safety information directly to members of the public. Their interactions with the public at different levels allows extension information such as whether or not a pesticide is needed, how to read a label, how to use the product safely, and steps they can do in protecting water and wildlife to be delivered to a public largely unreached by traditional programs.

Principal Deliverables:

Extension Publication

The draft publication is being reviewed by the co-authors for technical accuracy and readability. A commercial artist is in the process of creating illustrations for the extension publication. When the author review is completed, the document will be professionally edited and designed.

The current table of contents is as follows:

Work in Progress. Understanding Pesticide Principles and Practical Uses will be made available as a hard copy through Purdue's Media Distribution Center. It will be available by downloading at https://ag.purdue.edu/Extension/PPP/Pages/Publications.aspx. Pesticide safety and Master Gardener coordinators at land-grant universities will be mailed a copy of publication. Indiana Master Gardner instructors will have access to free copies to hand out at training programs or at community events.

Indiana Presentations: A total of 16 presentations were provided to 386 master gardener interns.

<u>2015</u>

- Monroe County Master Gardener Program. Bloomington, Indiana.
- TriCounty Master Gardener Program. Christney, Indiana.
- Floyd County Master Gardener Program. New Albany, Indiana.
- Porter County Master Gardener Program. Valparaiso, Indiana.

2014

- Kosciusko County Master Gardener Program. Warsaw, Indiana.
- Dearborn County Master Gardener Program. Aurora, Indiana.
- Tippecanoe County Master Gardener Program. Lafayette, Indiana.
- Delaware-Madison County Master Gardener Program. Alexandria, Indiana.
- Lawrence County Master Gardener Program. Bedford, Indiana.
- Lake County Master Gardener Program. Crown Point, Indiana.
- Jennings-Jackson Master Gardener Program. Seymour, Indiana.
- Monroe County Master Gardener Program. Bloomington, Indiana.
- Porter County Master Gardener Program. Valparaiso, Indiana.
- Blackford-Jay County Master Gardener Program. Montpelier, Indiana.
- Clay County Master Gardener Program. Brazil, Indiana.
- Miami County Master Gardener Program. Peru, Indiana.

The Impact of Cleaning Out Agricultural Sprayers and Tender Trucks on Water Quality Removing Herbicide Residues from Tank to Tip

Basic Information

Title:	The Impact of Cleaning Out Agricultural Sprayers and Tender Trucks on Water Quality Removing Herbicide Residues from Tank to Tip
Project Number:	2015IN379B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	04
Research Category:	Not Applicable
Focus Category:	Ecology, Education, Groundwater
Descriptors:	None
Principal Investigators:	Fred Whitford

Publication

1. Removing Herbicide Residues from Agricultural Application Equipment: How Proper Cleaning Helps Prevent Crop Damage and Improves Performance. PPP-108. 52 pages. https://ag.purdue.edu/extension/ppp/Documents/PPP-108.pdf

Indiana Water Resources Research Center Project Report

Report 2015 Program Report Format

Title: Water and Pesticides – Improving practices

Type: Outreach

Project ID: 2015IN379B

Period: March 1, 2015 – February 28, 2016

Congressional District: IN-004

Focus Categories: WQL

Keywords: groundwater/surface-water interactions, water protection

Dr. Fred Whitford

Director Purdue Pesticide Programs Office

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Problem: Weeds are very effective at capturing, diverting and using for its own use the nutrients and water intended for crops. Herbicides have become an important tool in no-till practices where they have replaced the plow in eliminating weeds and cover crops prior to spring planting. Their use in no-till or minimally tilled farm ground prevents soil erosion by allowing weeds to be controlled without having to till the ground.

But that same herbicide that provides so many benefits can become a liability when the spray mix is contaminated with a herbicide and injures a susceptible crop. Many of today's herbicides are active at very low rates. Cutting corners and saving time when cleaning equipment can cost thousands of dollars in damage claims even when small quantities are left in the spray system. "We don't have the time during the busy season," can never be the excuse when cleaning out sprayers during the rush of the application season. But cleaning a sprayer involves using hundreds of gallons of fresh water making the handling of that water critically important.

Publication

Title: Removing Herbicide Residues from Agricultural Application Equipment: How Proper Cleaning Helps Prevent Crop Damage and Improves Performance. PPP-108. 52 pages. First run printing, 10,000 copies; Second run printing, 10,000 copies. Hard copies of PPP-108 available from Purdue Education Store

Website Availability: https://ag.purdue.edu/extension/ppp/Documents/PPP-108.pdf

Purdue Press Release:
http://www.purdue.edu/newsroom/releases/2015/Q3/extension-manual-shows-herbicide-applicators-how-to-clean-equipment.html

Presentations

National

Cleaning spray equipment. Michigan Department of Transportation Operations Field Services/Roadside Applicator Training Workshop. **Lansing, Michigan**.

Cleaning right-of-way and forestry spray equipment: lessons learned from the agricultural industry. Appalachian Vegetation Management Association. **Roanoke, West Virginia**.

Rethinking the sprayer cleanout from start to finish. West Ohio Agronomy Day. **Ft. Loramie, Ohio.**

Sprayer and tank clean out. The Andersons Litchfield Agronomic Plot Day**. Litchfield, Michigan.**

Effectively cleaning sprayer tank residues. National Pesticide Applicator Certification and Training Workshop. **Philadelphia, Pennsylvania**.

Rethinking the sprayer cleanout-reordering steps and adopting new procedures. **Columbia, Missouri**.

Rethinking the sprayer cleanout. Farm Journal Corn College. **Heyworth, Illinois**.

Indiana (every attendee received PPP-108)

Rethinking sprayer cleanout: reordering steps and adopting new practices. Miami County Private Applicator Recertification Program. Peru, Indiana.
Rethinking the sprayer cleanout from start to finish. Wabash County Soil and Water Conservation District Annual Meeting. Wabash, Indiana.
Cleaning the sprayer: lessons learned from agriculture. AgBest Winter Grower Meeting. Hartford City, Indiana.
Paying attention to details when cleaning out the sprayer. Newton County Soil and Water Conservation District Getting Ready for Spring Applications Workshop. Morocco, Indiana.
Cleaning out the sprayer. Indiana Farm Bureau Spring Conference. Indianapolis, Indiana.
Cleaning spray equipment. Bartholomew County Private Applicator Recertification Program. Columbus, Indiana.
Rethinking the sprayer cleanout, reordering steps and adopting new practices. Kosciusko County Crops Management Workshop. Warsaw, Indiana.
Cleaning out your sprayer to prevent crop injury. Pulaski County Private Applicator Recertification Program. Francesville, Indiana.
Rethinking the sprayer cleanout: reordering steps and adopting new practices. John Deere Sprayer and Nutrient Application Training. Noblesville, Indiana.
Forestry equipment: preventing cross contamination. Indiana Arborist Association. Indianapolis, Indiana.
Rethinking your sprayer cleanout procedures. Ft. Wayne Machinery Show. Fort Wayne, Indiana.
Proper sprayer cleanout procedures. Fayette and Wayne County Private Applicator Recertification Program. Cambridge City, Indiana.
Cleaning out the sprayer. Hancock County Farm Management Update. Greenfield, Indiana.
The proper way to clean out your sprayer. Quad County Winter Crop Update. Wolcott, Indiana.
Tank cleaning challenges. Co-Alliance Applicator Workshop. West Lafayette, Indiana.
Removing herbicide residues from ag equipment. Daviess County Private Applicator Recertification Program. Montgomery, Indiana.
Removing herbicide residues from ag equipment. Martin County Private Applicator Recertification Program. Loogootee, Indiana.
Cleaning the sprayer: lessons learned from agriculture. Midwest Regional Turf Foundation Turf and Landscape Seminar. West Lafayette, Indiana.
Cleaning out the sprayer. Clark County Private Applicator Recertification Program. Charlestown, Indiana.
Cleaning out the sprayer. Harrison County Private Applicator Recertification Program. Corydon, Indiana.
Cleaning out the sprayer. Orange County Private Applicator Recertification Program. Paoli, Indiana.
Cleaning the sprayer. Crop Tech and Elkhart County Private Applicator Recertification Program. Millersbury, Indiana.
How to properly clean out a sprayer. Pinney Purdue Field Day. Wanatah, Indiana.
Cleaning out the sprayer. Red Gold Field Day. Elwood, Indiana.
Proper sprayer cleanout. Andersons Agronomy Field Day. Waterloo, Indiana.
Rethinking the sprayer cleanout. Northeastern Purdue Agricultural Center Diagnostic Training Workshop. Columbia City, Indiana.

Rethinking the sprayer cleanout. Association of Southern Feed, Fertilizer and Pesticide Control Officials. Indianapolis, Indiana.
Rethinking the sprayer cleanout: reordering steps and adopting new procedures. TriCounty Private Applicator Recertification Program. Mooresville, Indiana
Rethinking the sprayer cleanout, reordering steps and adopting new practices. Northern Indiana Soil Management Seminar. Goshen, Indiana.
Removing herbicide residues from the sprayer. Crop Production Services Applicator Training Workshop. West Lafayette, Indiana.
History of extension. Purdue New County Educator Training. West Lafayette, Indiana.
Keeping the pesticide trailer connected to the truck. National Railroad Contractors Association Weed Control Seminar. Indianapolis, Indiana.
Rethinking the sprayer cleanout: reordering steps and adopting new procedures. Purdue Crop Management Workshop. Warsaw, Seymour, Vincennes, West Lafayette, Indiana.

PowerPoint Availability: The PowerPoint has been provided at no cost to anyone making the request.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	13	0	0	0	13
Masters	6	0	0	0	6
Ph.D.	1	3	0	0	4
Post-Doc.	0	0	0	0	0
Total	20	3	0	0	23

Notable Awards and Achievements